

**University Research Linkages to the North Sea Oil and
Gas Industry**

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Declaration

The research contained in this thesis is my own work

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Abstract

This thesis explores research linkages between universities and the North Sea oil and gas industry. This sector contributes significantly to the funding of related academic research in universities and in response to this many university researchers and departments have created close ties with industry. The overall aim of this work is to improve the understanding of the nature of these linkages and of how university researchers, and the work they undertake, are influenced by industrial sponsorship and linkage.

An overview of the extent and nature of linkage in the sector is gained through a postal survey of university researchers. This survey also explores the working relationship between university and industry. These themes are investigated further through face-to-face interviews with both university researchers and industrial researchers and sponsors to obtain in-depth qualitative data on linkage activity. Findings show diversity in the range and extent of linkages, in benefits to both university and industry and in the working relationship between academics and industrialists.

The thesis further explores research linkage through a closer examination of the university researchers and their individual practices and strategies towards linkage. A range of institutional and attitudinal factors that influence and shape a university researcher's links with firms are highlighted and utilised to explain a researcher's propensity to create different types of university-industry linkages. Policy implications are discussed.

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1. Introduction

1.1 Introduction

This thesis is an exploration of university-industry research linkages in the North Sea oil and gas sector. The thesis presents findings from both a survey of university researchers and from in-depth qualitative interviews with university researchers and industry figures to explore and examine linkage activity. The research findings explore the importance of informal linkages and networking in university-industry research linkages and the benefits and barriers to linkage activity for both university and industry. The characteristics of linkage activity that are particular to the oil and gas sector are highlighted and the influence of the behaviour and attitudes of individual researchers on their linkage activity is examined. Furthermore, a framework is developed to classify and explain the behaviour of university researchers involved in linkages in this sector.

This chapter sets the scene for this study by, first, presenting a short discussion of university-industry linkages, their role, history and current policy context. Second, the oil and gas sector operating in the North Sea is discussed, and key sectoral factors that may influence university-industry linkages in this sector are highlighted. Finally, the structure of the thesis is outlined.

1.2 University-Industry Linkages: Context

The linkages between university research and industry have been the focus of much public policy attention in recent years (e.g. CST, 2000; Lambert, 2003). It is widely accepted that universities play a key role in supporting their local and national economies (Howells et al, 1998). The CST (2000) report 'Technology Matters' made a number of recommendations to government including more support for university research undertaken with industry. In particular, the report highlighted the key role of universities in providing skilled graduates into the labour force, recommended actions to encourage the transfer and exchange of staff between university and industry and to provide students with industrially based training to enhance this

process. More recently, the Lambert Review of University-Business Collaboration (2003) drew the attention of policymakers to the interactions between university and industry and highlighted the importance of promoting university and industry linkages. This review has reflected findings of other reviews of linkage activity that have been undertaken in recent years in the UK to inform government, research councils and universities (e.g. Howells et al, 1998; Charles and Conway, 2001; Salter et al, 2000).

The level of funding going into universities from the private sector is on the increase. Howells et. al. (1998) reported a steady increase in the research income from industrial sources into Higher Education Institutions (HEIs) of approximately 10% per annum, amounting to a total income of £183 million in year 1997-1998. In addition, this funding is forming an increasingly large part of the total income of universities. Charles and Conway (2001) reported that by 1999/2000 industrial funding of universities had reached approximately 15.5% of total university income, increasing by 7% on the previous year. This is now more than twice the funding generated from the research councils (UUK, 2002).

These reviews highlight the extent to which universities are looked upon to underpin the innovative capabilities of their national economies. Not only are they centres of research - developing new knowledge, techniques and skills that can be utilised by industry to further competitiveness - they also train the skilled graduates and postgraduates that form the workforce of industry in the future.

The UK Government have developed a range of funding mechanisms and incentives to promote the development of linkages universities and industry and to enhance the transfer of knowledge and skills. A number of incentives to enhance direct research linkages have been developed. These include: LINK programmes (which are jointly funded by research councils and government departments to develop long term research of strategic importance); Foresight programmes (where key player panels of university and industry representatives look into long term trends); and Faraday partnerships (which have developed a small number of core centres with high technology research organisations). Teaching and training initiatives have been

developed alongside these including: Co-operative Awards in Science and Engineering (CASE) studentships funded jointly by industry and research councils; and, Teaching Company Schemes (TCS) (now Knowledge Transfer Partnerships) targeted at introducing university expertise into small firms.

Despite these recent developments, academic-industrial links have been a long standing feature in the UK educational system. 'Red brick' universities were developed in the late 19th Century in the UK to support the industrial heartlands of the UK and the need to develop a technologically educated workforce (alongside the generating new research) was the key driver behind the development of the polytechnic universities (Howells et al, 1998). However, it has only been in more recent years that the policy significance of these linkages has become recognised (Salter et al, 2000). This has led not only to the development of government routes to support linkage, but also to the growth of an increasing body of literature addressing the nature, benefits and best practice in university-industry linkages (e.g. Senker, 1990; Davenport et al, 1999; Scott et al, 2002; Shane, 2002; IoIR, 2003).

The increasing focus on the value of universities to industry and the rise of university income from intellectual property rights (IPR) and spin off companies have, in particular, led to developments in the understanding of the roles and operation of university research. Etzkowitz (1994,1998) found that trends such as these have led to a change in the research agendas and norms of scientific behaviour of researchers in universities, specifically leading to a move away from purely teaching and research to a culture that incorporates an element of entrepreneurship in the work of the academic. These trends are reflected in the research of Gibbons et al (1994) who suggest that university research is moving into a new mode of knowledge production, with greater collaboration and transdisciplinarity, and with research now being created more in the context of collaboration rather than in the context of a specific community. This shift has raised concerns that too greater shift in the commercial direction by academics could result in "eroding the genuine spirit of enquiry without which innovation is not possible" (Webster, 1994: p.125).

This study contributes to this body of knowledge examining interactions between university and industry through exploring research linkages in the oil and gas sector – one of the most important industries in the UK and a sector in which university-industry linkages has had little research attention.

1.3 The UK Oil and Gas Industry

The exploration and extraction of oil and gas in the North Sea is a major industry in the UK, employing in excess of 270,000 and investing some £3bn per year in new developments (PILOT, 2000). It has provided £89 billion in revenue to the UK and is responsible for approximately 17% of UK industrial investment (OGITF, 1999). The operating environment of the industry is complex and changing and is faced with some considerable challenges. The sizes of new oil and gas discoveries are diminishing and the viability of many marginal fields varies with global oil price fluctuations. Added to this are a mixture of uncertainties in knowledge related to the geological structure of oil fields, associated difficulties in determining recoverable reserves and in designing appropriate development scenarios.

Small fields and larger fields reaching the end of their life are numerous and could make a large impact on the economy of the UK if their assets can be fully realised (OGITF, 1999). This requires constant developments and refinements in the knowledge and technologies utilised to explore and produce in oil and gas (PILOT, 2000). In addition, the industry is moving into deeper and significantly more hostile sea environments, demanding further technological development (Pickering, 1999). It has been suggested that in order to meet this increasing demand for new knowledge and innovations, research linkages between university and industry are an excellent but underused means of optimising the resources available to the oil industry (RSE, 1997).

The UK offshore oil and gas industry involves many diverse technological and service industries from a wide range of industrial sectors. These different industries all interact in a large network, which has been conceptualised as comprising three types of actor. (summary of Crabtree et al, 1997: p183). These are:

Operators. The operators are the companies which licence the oil and gas fields and take the legal responsibility in running them. They consist of large multi-national firms such as Shell, BPAmoco, TotalFinaElf and Exxon. These operators subcontract large amounts of their exploration and production functions, have integrated downstream capabilities and retail their own petrochemical products.

Contractors/Service Companies. The contractors are a large range of companies that the operator utilises to arrange and provide services to the industry, i.e. running the oil field in terms of drilling, production services, maintenance and general oil field support. These companies include the likes of Schlumberger, AMEC and Baker Hughes.

Suppliers. There are two main types of supplier firm in the industry. First, those that supply the basic items such as ‘nuts and bolts’, delivery services etc.; and second, suppliers of highly specialised technological products and services. This latter category has to invest highly in innovation to meet the needs of the industry. Some of these are large firms, but a significant proportion of this sector is made up by small and medium sized enterprises that have established themselves in the oil areas of Scotland.

1.3.1 The innovative Environment in the Industry

The North Sea oil industry has grown over the last thirty years to create a new technologically advanced regional network of organisations underpinning the service and supply needs of the sector (Pickering, 1999; Collingridge et al, 1994; Patten, 1985). After initially being dominated by large multi-national oil firms, the industry has been joined by numerous smaller independent firms and a number of start-up companies (Pickering, 1999). There was a strong local development of these independent firms in the Aberdeen area to meet the demand for novel oil-related services and supplies, and these have been able to compete with the larger multi-nationals through their in-house technological expertise (Bower and Young, 1995). Nearly half of the firms in this sector “a) were founded since the discovery of oil, b) were UK based and, c) had less than 220 employees” (Crabtree et al, 1997; p.182)

The North Sea provided a highly innovative technological arena for those companies initially involved in production (UKOOA, 1993). Although experienced with the worlds first off-shore oil discoveries in the Gulf of Mexico and the Persian Gulf, the more hostile environment of the North Sea proved to have major difficulties for these companies (Pickering, 1999). The production rigs, for example, have to be strong enough to withstand huge sea swells, wind gusts and continuous salt corrosion (Patten, 1985). Subsequently, development costs in the North Sea were shown to be four to six times greater than in other areas of oil and gas extraction (UKOOA, 1993). Although this may in part be attributable to the adverse environment, the early development in the North Sea fields proved to be 'over expensive' (Collingridge et al., 1994). The new technological demands placed upon developers of North Sea oil and gas fields had resulted in highly expensive large fixed platforms being developed early on, along with the other infrastructure that had been "hurriedly developed in the mid-1970s" (Collingridge et al, 1994: p.172). This led to a situation that included the use of many "non-standard materials, equipment and procedures, uncontrolled documentation and certification costs, unbalanced financial risk exposure, poor communication and adversarial contracting systems" (UKOOA, 1992). The relationships between the suppliers, contractors and operators was conducted in the form of a multiple linkage network between all levels of the industry. This meant that all firms, even the smallest SMEs, had the opportunity to interact with the large oil operators (Crabtree et al, 1997).

To counter the inefficiencies in the industry the UK Offshore Operators Association developed CRINE (Cost Reduction Initiative for the New Era) – an industry and government supported initiative to stimulate collaboration and improve competitiveness (UKOOA, 1993). CRINE suggested that this multi-level, multi-subcontractual method of operating led to a duplication of resources and a fragmentation between too many suppliers (UKOOA, 1993). This, allied with trends towards downsizing in industry, shifted the methods of contracting in the industry. The CRINE report (UKOOA, 1993) promoted the use of 'risk-reward' contracts, rather than the then existing adversarial methods. It was suggested that a goal setting philosophy would stimulate innovation in the sector, with the need to communicate,

align objectives and share rewards as driving forces behind the changes (UKOOA, 1993). These themes and examples of best practice have been refined and developed by subsequent industry-government initiatives such as the Oil and Gas Industry Taskforce (OGITF), PILOT, and LOGIC (Leading Oil and Gas Industry Competitiveness).

Consequently, the industry has seen a shift of functions from the operators to the contractors, creating new relationships and new responsibilities for the contractor (Crabtree et al, 1997). They have had to grow and subcontract out in areas in which previously they had no expertise, or acquire new facilities to deliver the service required by the operators. Bower and Young (1995) identified that in this system smaller supplier firms were much less likely to collaborate with the operators, distancing themselves from them and forcing them to work with contractors who they may not have worked with previously. This adversely affected the innovative environment with these “changes in contracting reducing direct contact with end users and reducing information flow” (Bower and Young, 1995: p.414).

The CRINE report highlighted that trust is essential to the success of these multi-firm partnerships (UKOOA, 1997). Williamson (1983) describes how those inside industry set the norms and use collective experience to enforce trustworthy behaviour. The lack of trust in the oil and gas sector (Crabtree et al, 1997; Bower and Young, 1995) implies that collaborations and alliances will be difficult to manage and maintain. Crabtree et al (1997) highlight the restructuring, downsizing and changes in contracting methods as key problems and reasons behind this lack of trust. This has resulted in a situation where contractual relationships are complex and multi layered - user-supplier, supplier-user, collaborative and competitive relationships exist concurrently between the same firms, resulting in complex and conflicting relationships within which effective collaboration may have to be maintained (Bower and Young, 1995). At the same time, firms still have to act competitively on a different front. “It was frequently the same individuals that interacted within the various relationships, raising the issues of personal as well as corporate integrity” (Crabtree et al, 1997: p.188). In addition, legislation forces firms

to contract out work to organisations that have the same capabilities as their own to prevent particular firms gaining a monopoly on projects.

These problems create an environment which is low in trust and has not produced the courteous cross-industry relationships necessary for effective and efficient business interactions (Williamson, 1983). Contractual relationships have developed rapidly and both inter-firm and internal relationships appear to have suffered as a result.

There is an assumption in the industry that players will act opportunistically to gain a competitive advantage, resulting in a lack of trust and withholding of technological information. However, personal relationships are seen to be important and the interfirm relationships in the sector have been described as 'incestual' (Crabtree et al, 1997).

Dickson (1996) notes that trust is vital to successful collaborations on many levels. The development of trust from a scientific respect through collaborations creates a business environment of both professional and scientific trust. However, the research and policy discussed above suggests that the North Sea oil environment does not foster the stable relationships needed to generate this trust. In addition, research has shown that small firms in the sector find it difficult to, or may be wary of, fully committing themselves to technological collaboration as larger companies may steal technologies (Bower et al, 1997). This suggests that these barriers to knowledge flows between companies could be highly damaging in terms of the technological development and innovation in the industry.

In response to these problems, and the work of the OGITF, a number of independent organisations were launched. One of these is the Industry Technology Facilitator (ITF), a not for profit organisation owned and funded by 16 oil and gas operating companies. It was formed in 2000, and aims to support technological development by communicating industrial technological needs and stimulating dialogue between the full range of companies operating in the industry, academia, government and industry associations. ITF is used as a vehicle through which its member companies can fund joint industry projects (JIPs). The organisation promotes areas for research

and development to smaller companies and academia to act as a stimuli to innovation in the sector.

1.3.2 Other Industry Factors Affecting Technological Innovation

Initial high yields and accompanying high oil prices made early fields highly profitable but at the same time hampered technological development as large oil firms were allowed to be complacent with respect to technological innovation and confident about future prospects (Collingridge et al, 1994). Subsequent collapses in the price of oil and the resulting decrease in profit margins in the upstream industry, along with a need to develop the smaller offshore fields, has forced the industry to economise. This has been done by encouraging innovation and collaboration and the standardisation of many of the technologies used (Pickering, 1999; Collingridge et al, 1994). In addition, recent years have seen the mergers of a number of the major oil and gas companies, resulting in downsizing and a subsequent rationalisation in the resources devoted to innovation.

On the other hand, the high density of technology based firms in and around Aberdeen, the centre of the North Sea oil supply base, has facilitated the innovative capability of the industry as a whole (Bower and Young, 1995). Although the contractual changes that have occurred have severed many direct contacts to the end users of technology, and hence to outlets and ideas for innovative capacity, the smaller firms, through their geographical proximity, have been able to maintain a sufficient level of information flow to seek out new technological opportunities (Bower and Young, 1995). This knowledge network was identified as existing through both business contacts and social interactions. These types of network are important routes for the formation of collaborations (Davenport et al, 1999), but a potential cause for the incestual business relationships (Crabtree et al, 1997) that may stifle innovation for the sector as a whole.

It is important, particularly for smaller firms in these networks, to nurture relationships with larger firms without giving away knowledge that may be vital to their competitiveness. The technology leaders are at an advantage in this respect

because of their power to manipulate their environment by bypassing alliances, implying that expertise is as effective method at manipulating the business environment as size of firm (Bower and Keogh, 1997). But any information transferred carries an element of risk, and companies in these networks need to be able maintain ownership and as a result their competitiveness.

1.4 Universities and the Oil and Gas Sector

In response to the rapid growth of the oil and gas industry in the UK many universities have built up expertise in the scientific and technological areas related to the industry. There are opportunities for, and instances of, research linkages to industry within many of these universities (Bower and Keogh, 1996). Indeed, industry inputs have influenced many aspects of university work from equipment and tools for researchers through to teaching aids for students (Turner and Holdsworth, 2002). In Scotland, the more academic research related to the industry is focused upon the universities based in Glasgow and Edinburgh, whereas the more industrially oriented research is centred upon the Aberdeen universities (RSE, 1997). Aberdeen, as the centre of the Scottish oil industry, has the advantage of proximity to the majority of the technological companies involved in the industry, and this may account for the different emphasis. The majority of the universities forge linkages from traditional disciplinary departments, but some have specialist centres based around the industry intended to tap into the opportunities that oil and gas have to offer. The Department of Petroleum Engineering at Heriot-Watt University in Edinburgh, and the Mechanical and Offshore Engineering department at Robert Gordon University in Aberdeen are examples of the response Scottish universities have made to rapid growth of the industry in the North Sea. Other industry focused university departments have also developed across the UK.

To complement and expand the levels of linkage between university and industry in Scotland, an energy focused 'Intermediary Technology Institute' was opened in late 2003 in Aberdeen (www.ititenergy.com) with support from the Scottish Executive. Its role is to act as a centre of excellence for research and development to stimulate

links between university research and the companies in the sector, and support companies in the development of innovative ideas.

The different academic institutions have made many linkages to the industry, varying from consultancy work to sponsored research projects and sponsored research buildings and centres. However, a Royal Society of Edinburgh lecture indicated that the linkage capacity of the universities is not being maximised, and that the linkages are not always easy to instigate due to the difficulties in producing mutually acceptable outcomes to linkages (RSE, 1997). This review also found that both universities and industry representatives indicated differing awareness of each other's capabilities (RSE, 1997). Many of the industry representatives indicated that they were fully aware of the research expertise and capabilities present in the universities, but felt that the research being produced was not practical enough for industry to utilise. For their part, university representatives felt that industry was not sufficiently cognisant of the multi-disciplinary research potential present in the universities, but acknowledged that they should make themselves more aware of the needs of industry so as to be more able to shape research agendas to suit their needs (RSE, 1997).

1.5 Summary

The North Sea oil and gas industry is an environment of major innovation. It is a highly complex and varied industry with opportunities for both inter-firm and university-industry research and development linkages. Low levels of communication and trust between firms has been identified as a major impediment to progress in the industry. Furthermore, there is a recognised need to maximise the sharing of knowledge between industrial and academic environments. This provides an interesting background with which to study linkage and the transfer of knowledge between university and industry. In addition, although many investigations have been made into inter-company links in the oil and gas sector, little research has been undertaken into university-industry linkages in the sector, so there is scope for a deeper understanding of linkages to be undertaken in this context.

This thesis presents an exploration of one sector – the UK oil and gas industry. It has been reported that there is “abundant evidence of the contribution of academic researchers to innovation in the sector” (Bower and Keogh, 1996: p.217), and research has classified that the contribution of academic research to the oil and gas sector is ‘high’ relative to other sectors (Salter et al, 2000). This places it broadly equivalent to aerospace, motor vehicles and telecommunications in its academic contribution to industry, but below pharmaceuticals and computers. Despite this ‘high’ academic contribution to industry, it has been reported (RSE, 1997) that university and industry are not maximising their opportunities to link, and are not fully aware of each other’s capabilities. This study is important in that it contributes to this research of university-industry linkage in the sector through exploring not only the level of linkage between university and industry, but also the attitudes and behaviour of researchers involved in linkage. As a result it is able to explore the understanding that university and industry researchers involved in linkage have of each other and the potential for maximising the opportunities for university-industry linkages in the sector, as identified by RSE (1997) above.

The particular characteristics that may be evident in any one sector make it difficult to generalise findings to any others and since the contribution of universities to the sector has been found to be high, the findings from this research may not be relevant to sectors with little contribution from academia. However, as is stressed throughout this thesis, many key themes that arise in the research literature as being relevant to understanding university-industry linkages across all sectors are echoed in the findings presented in this thesis. To this degree, the thesis contributes to research understanding of linkage and policy in other sectors by providing an in depth account of the linkage in the oil and gas sector. This thesis also allows findings from other sectors to be contrasted to these.

1.6 Thesis Outline

This thesis will be presented as follows: Chapter two describes the existing body of literature on university-industry links, highlighting key themes and factors involved in linkage. This provides a background from which the linkage in this sector can be

examined and presents the research questions for the thesis. Chapter three describes the research methods utilised in this study. These comprised a postal survey of university researchers linking with industry and in depth qualitative interviews with university and industry figures. The focus of the research shifted during the data collection process away from what was initially intended to be a symmetrical study of universities and firms in the sector to a study more closely located on the university researchers. The reasons for this are outlined and resultant shifts in the research questions described.

Chapter four describes the results from the postal survey of university researchers involved in industry linkage. These are examined around three main themes: the types and extent of linkage; the benefits of linkage; and the relationship between university and industry. The survey provided an overview of the linkage activity of university researchers in the sector. This demonstrated that the majority of university-industry linkages were through the JIP system of multiple companies sponsoring university research projects. The general relationship between university and industry was found to be positive and key sectoral differences were identified, suggesting that linkages are more beneficial and interesting to academics in the oil industry than in other sectors. However, problems were noted as a result of the low levels of input by industry and the difficulty university researchers found in making contacts to potential funders.

Chapter five extends the findings from the survey and utilises data from interviews conducted with university and industry figures to more closely examine linkage in the sector. The chapter focuses upon the informants descriptions of the extent and types of linkage and the benefits to both sides. This indicates that both universities and industry gained much from the linkage, and that the research being undertaken was stimulating for the university researchers. The results suggested that trust and mutual respect existed between university and industry, and that this was key to effective linkages. Differences in the attitudes and behaviour of university researchers are identified.

Chapter six further examines university and industry informants reports of their linkage activity and focuses on the relationship between them. Results indicate the huge importance of personal contacts and informal networks in generating instances of industrial funding for universities and in transferring knowledge and skills. The insights into the differences between university researchers and their practices and attitudes to linkage are extended. This chapter also discusses university and industry insights into the use of ITF as a route to gaining funding.

Chapter seven utilises data gathered throughout the course of this study to develop a framework to understand and explain variation in the linkage behaviour of different university researchers. This utilises factors relating to the institutional environment, the behaviour of university researchers, and their attitudes to linkages to add depth to the understanding of how and why linkages are undertaken.

The concluding chapter draws together the main findings produced in the analysis. It explains how the thesis contributes to the understanding of university-industry research linkage in the UK oil and gas sector. Policy implications and areas for further research are discussed.

2. Literature Review

2.1 Introduction

This thesis is an exploration of university-industry linkages in the oil and gas sector. In particular it focuses on the types and benefits of linkage and, building on existing literature in the field, develops an understanding of the reasons why university researchers enter into linkage activity and seeks to explain the differences in behaviour between university researchers in this area.

This chapter sets the scene for this endeavour by reviewing literature informing understanding of university linkage in five key sections. The first section discusses two features of the literature that shape understanding of linkage and that are particularly relevant to the analysis in this thesis. These are the two way nature of university-industry linkages and the terms that are used to describe linkage.

Second, research reviewing the interaction between university and industry, primarily comprising reviews and evaluations to inform policy or business management, are presented. This enables the broad characteristics of university-industry linkages (including mechanisms of linkages, benefits and barriers to linkage behaviour) across all sectors to be discussed.

Third, research that has sought to explore what is transferred (and how) in linkage is reviewed. This extends the understanding of linkages described in the first section to explore more closely the nature of what is exchanged in linkage and the factors that may influence the extent of linkage behaviour between university and industry. These discussions explore the process of linkage and highlight areas (such as the different types of knowledge that can be exchanged between partners in linkage, factors that influence the extent university linkages in different situations and importance of informal linkages) that shape this investigation into linkages in the oil and gas sector.

Research exploring and explaining factors related to individual researchers are explored in the fourth section of this chapter. Research that has sought to map the behaviour of researchers is reviewed and this is followed by a review of the research that has sought to explain the reasons for this behaviour.

In the final section of the review the literature on factors that can make linkage work is presented.

2.2 Understanding University-Industry Linkage

Before embarking on a review, it is important to highlight two key features of the literature that influence the way university-industry linkage is understood. These are: the use of the term ‘collaboration’ to describe a range of mechanisms of linkage between university and industry; and the understanding that university-industry linkages are not a one way process of transferring knowledge from university to industry, but are an interactive process involving the two-way flow of knowledge. These two features are described in this first section to shape the understanding of the literature that follows.

2.2.1 Defining Collaboration and Linkage

A range of terms has been used to by researchers (and indeed those involved in research linkages) to describe the ways in which university and industry interact. These include terms such as ‘links’; ‘collaboration’; ‘co-operative research’; ‘collaborative research’; ‘joint research’; ‘research alliances’ and so on. These terms refer to, and suggest to the reader, different levels and types of interaction and linkage between university and industry but their precise meaning in any given context is often not specific. Indeed, ‘Research Collaboration’ is almost ubiquitous as an overall term to classify any linkages between university and industry related to research activity.

Many studies in the US refer to university-industry joint research centres (e.g. Florida 1999; Roessner, 1993; Russo and Herronkohl, 1990) as locations for collaborative research, and this would appear to be a clear label accurately describing centres

where university and industry scientists work together side-by side. However, the broad use of this label can lead to some confusion. Much of the research on university-industry ‘collaborations’ deals with research that is primarily undertaken in university settings, with limited commercial input. For example, the CURDS report on Higher Education - Business Interaction (Charles and Conway, 2001) identifies sponsored research, collaborative research, sponsored research students (and others types of linkage) under the broad description of ‘collaborative research with business’. Similarly, Butler and Birley (1998: p.101) classify collaborations as “agreements to carry out research [in universities]” – typical examples of which are funding a senior post-doc for a number of years, or a university having a research grant from industry.

These instances would not appear to be fully ‘collaborative research’. Rather they are university undertaken, industry-funded work. However, I would argue that although researchers are not working side by side, collaborative behaviour in some form – that is, the act of university and industry working together towards a common goal – does occur in all instances of linkage. For example, even in the case of an industry funded, university undertaken piece of testing or consultancy work, there is still *collaboration* occurring, as university and industry researchers need, at the very least, to work together to agree goals and exchange data relating to the work. However, to classify this as ‘collaborative research’ is potentially misleading, as the interactions between university and industry researchers do not extend to working together side-by-side on the testing or consultancy work.

As this chapter will suggest, and the thesis as a whole indicate in the cases of the linkage I examine, university and industry researchers interact or collaborate through informal exchanges of information during all linkage mechanisms (see, for example, Faulkner and Senker, 1995b; Davenport et al, 1999) (the literature discussing these interactions is explored further in section 2.4). Consequently, for the purposes of understanding and clarity, I will define collaboration in university-industry linkage as any example of university and industry researchers or managers working together to reach a common research-related goal. However, so as to not raise the problem of

distinguishing certain types of research linkage as ‘collaborative’ or not, I will use the term ‘research linkage’ in discussing all mechanisms through which university and industry interact. This will make discussion of linkage mechanisms in this thesis (i.e. mapping what types of linkage mechanism occur in the oil and gas sector) distinct from the discussion of the *collaborative behaviour* of those involved in research linkages (i.e. to what extent partners work, and seek to work, with each other in the oil and gas sector). This exploration of the collaborative behaviour of researchers in this study expands the understanding of the linkage process and explores what makes linkages work. The factors that influence this are explored in the later stages of this chapter and are addressed in final part of my analysis in this thesis.

2.2.2 University-Industry Linkages as a Two-Way Process

Research into university-industry linkages has addressed various aspects of university-industry interactions, but much of the literature has sought to assess the value of research in universities to business and national economies (e.g. Salter et al (2000) for Committee of Vice Chancellors and Principals; and Scott et al. (2002) for the Office of Science and Technology), or to university funding bodies (Charles and Conway, (2001), and Howells et. al. (1998) for the Higher Education Funding Councils), and does little beyond describing the benefits and types of interaction that occur. This research tends not to explore the benefits to universities of linkage (beyond the income that research linkages generate) and, as a result, reinforces a perception of a one-way flow of technology and knowledge from university to industry, perpetuating a view of universities purely as generators of knowledge to be taken up by industry.

This echoes findings from the early studies of innovation. The ‘traditional’ approach of understanding the relationship between university and industry (as part the innovation process as a whole) was through the ‘linear model’. This approach is characterised by a number of simple steps that describe the relationship between ‘basic’ scientific research and the technological innovations of industry. In this model “basic research produces a flow of theories and findings that are refined

through applied research, tested in the development process and finally commercialised as industrial innovations” (Steinmueller, 1994: p.54).

This linear approach is powerful as a result of its simplicity. It is often used to assist in the policy setting and to influence firm strategies (Tait and Williams, 1999), and to shape research into the university-industry linkages (e.g. Harmon et. al. 1997). It has, however, regularly been found to be at odds with the empirical evidence (e.g. Williams and Tait, 1999; Rosenberg, 1994; Steinmeuller, 1994; Freeman and Soete, 1997, Scott et al., 2002). The model has been criticised for many key reasons. Scott et al. (2002: p.3) summarise these reasons as follows: “it does not allow for the fact that technology leads to science, that science is often developed as a result of a need to understand new technologies; it overlooks the fact that industry researchers often undertake science and publish results; it ignores the need for scientific expertise in industry in order to absorb results; it does not account for variety in linkage across sectors; it does not describe innovation that occurs in industry; and it does not account for the variety of additional ways, such as feedback loops, and incremental innovation in which linkages operate and benefits arise”.

These failings of the linear model have led researchers to produce more realistic models of the innovation process, and as a result describe more accurately the relationships between the university and industry. Such models (e.g. the chain-linked model - Kline, 1991) are necessarily more complex in order to take into account of the multiple paths and sources of scientific and technological development. In highlighting factors such as the importance of ‘feedback’ loops between the research, development and production elements of innovation, these non-linear models indicate that technology is *exchanged* between university and industry. Subsequently, key to an effective investigation into the industrial use of university research is the need to acknowledge and gain an understanding of the two-way, rather than linear, relationship between the two settings.

The analysis of the literature and the data collected in this study is framed by this understanding that there is a non-linear relationship between university and industry and that benefits are gained and knowledge provided by both university and industry.

Without this perspective the linkages between university and industry, the relationships between researchers in linkage and the motivations and attitudes of university researchers in particular cannot be fully understood. This study, therefore highlights the flow of knowledge and information both from industry to university and vice versa.

2.3 Reviews of University-Industry Linkage

A large number of researchers have sought to review the linkage activity between university and industry and, as indicated in section 2.2.2 above, much of the literature has focused on reviewing the extents and types of linkages. Indeed, it has been acknowledged that much of the literature does not have a strong theoretical background to investigate and explain these interactions in depth (Giesler, 1995) and much research has been descriptive rather than analytical (Faulkner, 1995). However, this research is valuable in exploring the mechanisms, benefits and barriers of university-industry linkage which are vital in giving context to any in-depth study of this activity.

This section of the chapter discusses these reviews of university-industry linkage and enables key mechanisms, benefits and barriers to be identified to give context to the further investigations of linkages presented later in this chapter.

2.3.1 Mechanisms of Linkage

Charles and Conway (2001: p.17), in their review of university-industry interaction in the UK for the Higher Education Funding Councils, identified four broad categories of interaction or mechanisms of linkage. These comprise: research-based services; exploitation of existing knowledge; people-based mobility and exchange schemes; and spin-off and forming new companies. These mechanisms will be described briefly below, to give context to this study of university-industry linkages, and to form a background to further investigation into the characteristics of linkages.

Research- based activities focus on the creation or development of new knowledge through sponsored research and through the shared or combined use of scientific and

technical facilities. This predominantly involves industrially sponsored university research projects (requested by the clients, or agreed between the university and industry) and research income received through a competitive process from the research councils and including cases where a business may have provided additional or matched funding (Charles and Conway, 2001). These projects are long term linkages, typically two to three years, and make up approximately 12% of the total research income into UK universities of which 60% of this is research commissioned by industry (Howells et al, 1998). These projects are operate on the basis that the university undertakes the work with often little direct involvement by industry staff. Charles and Conway (2001) noted that the majority of these types of linkages were made with large firms (firm size as a factor in determining linkage is discussed further in section 2.4.3).

Exploitation of existing knowledge includes activities such as consultancy, patenting/licensing and testing. These mechanisms are likely to be short-term linkages through which experts from university are used to bring specialist services into an organisation that cannot be sourced internally, or to provide impartial expertise to enhance the credibility or ensure the standard of particular technologies that they develop (Rappert et al, 1999; UUK/AURIL, 2001). These types of linkage may be used as a way of partners 'dipping their toes in the water' to assess the possibility of future, larger scale, linkage activity (Davenport et al, 1999). Small-scale formal linkages such as these allow firms and university researchers to assess potential partners or provide a basis for informal communication without a major investment of financial or personnel resources. However, much of the value of this type of linkage is in the personal knowledge and expertise of the university researchers (Charles and Conway, 2001: p.59). As a result, gaining access to particular individuals in university is key to developing these links (a theme that is developed in chapters 4, 5 and 6 of this thesis).

People based mobility and exchange schemes involve the transfer of knowledge between university and industry through the exchange and sponsorship of staff and students. This includes activities such as CASE Studentships (jointly funded

doctoral students by the firm and academic research councils); sponsored university staff, University/Industry staff exchanges, and KTP (formerly TCS schemes) which are government supported schemes to place graduate researchers in small companies (see www.ktponline.org.uk for a more detailed overview, or Robson (1996) for a review). These types of linkage may be used by industry not only for the outcomes of the research, but also as a potential recruitment tool (to assess the student or staff for future employment) (Scott et al, 2002; Salter et al, 2000). Internships and sabbaticals may also be used by the company to gain training and assessment for potential future recruits, making the employee selection more certain and hence ensuring that the firm remain competitive by employing the most suitable people (Bloeden and Stokes, 1994).

Linkages are also created between university and industry through universities both training industry staff (Blumenthal et al, 1986) and using industry contacts to teach students through placements in industry or researching industrial problems (Santoro and Chakrobharti, 2002; Bloeden and Stokes, 1994).

Spin offs and new companies are the firms created by university researchers to enable the commercial exploitation of new research (Charles and Conway, 2001). This has been an area of increased activity in recent years with approximately half of UK universities reporting these routes to commercialisation (Howells et. al., 1998). Universities have also taken steps to promote linkages between university and industry researchers through 'science park' initiatives. Unfortunately, although designed to stimulate interaction between academia and industry, studies have found that that firms located in science parks have no greater links with universities than other firms in the area (Massey et al, 1992) and prime motivations for firms locating at these sites are more likely to be based on the quality of accommodation rather than potential for linkage (Vedovello, 1997).

There are therefore a diverse range of linkages currently used between university and industry. These different mechanisms of research linkage provide different benefits to both university and industry and it is these that are explored in the next section.

2.3.2 Benefits of Linkage

The research literature reveals a range of forms of benefits of linkage to both university and industry (e.g. artefacts, knowledge, information, skills, public relations etc – see tables 2.1 and 2.2 below). As a result, identifying (and even understanding) all the benefits that arise out of an instance of linkage is not straightforward. Most research related linkage activity does not occur in isolation – it is part of a wider spectrum of work that continues before, during and after any particular instance of linkage (Scott et al., 2002). Therefore, attributing any benefits to the partners of particular instances of linkage can at times be problematic (see, for example, Georghiou and Metcalfe, 1993; Luukkonen, 1998).

Linkages often do not provide direct benefits to those involved. As Salter et. al. (2000: p.60) note, “firms are less likely to use specific data or conclusions than they are to draw upon new understandings or approaches in searching out solutions to innovation problems”. The types of benefits gained are related to the type of linkage mechanism and the aims and motivations of the researchers involved but it is unlikely that all of the benefits received from a particular linkage will be expected at the outset: “Some of the benefits are direct, while some are indirect. Equally, some are deliberately brought about by ... the decisions of researchers, universities or firms, while some are unplanned or unpredictable” (Scott et al, 2002: p.9).

Furthermore, the benefits from the informal exchanges that occur within formal linkages are often as productive as formal interactions themselves (Lee and Gaertner, 1994). Informal linkages are discussed in more depth in 2.4.1.

Despite these problems it is possible to identify a range of possible benefits of linkage for both industry and university. These shall be outlined briefly and will present a foundation for exploring the motivations for, and differences in, the linkage activity explored in this thesis.

Industry Benefits

Table 2.1 describes the range of potential benefits that industry can gain out of linkage. They are grouped loosely into research-related, existing knowledge-related

and non-research related benefits to relate these to the categories of linkage mechanism described in the previous section. These categories are overlapping and interrelated and different benefits may be gained from each type of university-industry interaction. However, broadly speaking the prime benefit gained is related to the nature of the research linkage mechanism, for example a firm wishing to develop new knowledge as the key benefit, is likely to choose to link with universities through a research-related mechanism (such as a sponsored research project). Similarly, if they are wishing to access existing knowledge or skills, they will link through mechanisms such as consultancy or testing.

Table 2.1 Benefits to industry – non-ranked. (Table utilising information from tables in Faulkner and Senker, 1994: p.682[+] and Salter et al, 2000: p.59[#])

Benefits of University Linkage for Industry
<i>Research related</i>
• New scientific information and methodologies #
• Specific expertise + & problem solving #
• Increasing the stock of useful knowledge #
• Strategic advice +
• General assistance +
<i>Existing knowledge related</i>
• Assistance with experimentation +
• Skills in techniques, methodologies, instrumentation +
• Access to research equipment +
• Access to research materials +
• Product testing +
<i>Non-research related</i>
• Networking and stimulating interaction #
• Training of skilled graduates #
• Public Relations (PR) +
• Keeping staff happy +
• Recruitment +

Non-research related benefits can be a desired direct or additional side benefit to linkage. Interactions with university research can be used as an exercise in keeping industry staff happy through maintaining a research related element to their work. This could in turn lead to larger opportunities for linkage that may not have existed previously (Bloedon and Stokes, 1994). The high profile sponsoring of research in the public sector may help to improve the PR of the firm and in addition may help in the recruitment of scientists to the firm (Faulkner and Senker, 1994). The

recruitment of skilled graduates can be a major benefit of university-industry interactions. “New graduates not only bring knowledge of recent scientific research and contacts in universities, but also abilities to solve complex problems, perform research and develop ideas” (Salter et al, 2000: p.60).

University Benefits

The primary motivation for universities linking to industry research funds is often to gain access to funding for research (Howells et al, 1998; Jones-Evans et al, 1999).

University funding provided by industry is much needed at a time when traditional funding from governments is becoming increasingly stretched and reduced.

However, there are other additional benefits to be gained by universities from the industry linkages. Fig. 2.2 shows the top nine motivations for university researchers in linking to industry as found by a survey of all UK universities.

Table 2.2: Factors motivating links with industry in terms of research contracts and income (all UK HEIs) (Howells et al, 1998: p.21)

Rank	Motive
1	To access industrial funding
2	Collaboration with industry is a strategic institutional policy
3	To find an exploitation outlet for research capabilities
4	To access complementary expertise
5	To provide an outlet for research results
6	To access state-of-the-art equipment & facilities
7	To contribute to local economy
8	Government policy and/or political pressure
9	To contribute to UK economy

The findings of Howells et. al. (1998) demonstrate other important benefits beyond funding for the university in linking with industry. It can be useful for researchers to apply their research results to practical situations as the information that can be gained from ‘real life’ testing can assist in the development of research (Santoro and Chakrabharti, 2002). In addition, the access to relevant expertise held by those in industry, and to state-of-the-art equipment and facilities held by companies, can greatly contribute to university research. In certain technological areas the level of research related equipment, expertise or information in industry may exceed those in academia and linking with industry may be the only way that academics can gain

access to this expensive or extremely specialised knowledge (the reverse is also possible – as outlined in the benefits to industry above).

The benefits of linkages to both university and industry occur through a variety of formal routes (e.g. research outcomes) and informal routes (e.g. discussions and advice outwith the linkage) (Lee and Gaertner, 1994) in the long and short term, and in ways that may not be directly related to the research itself (e.g. PR and recruitment) Faulkner and Senker, 1994). It is crucial to note that although most linkages involve a one way flow of funding (from industry to university), all linkages ranging from informal contacts though to sponsored posts, projects and research centres involve a two way flow of knowledge and expertise.

It is important to note that the table above lists motivations of linkage, rather than benefits. Research exploring the benefits of linkage to university research is scarce relative to research into industry benefits, hence the use of this table. This reflects the use of research into university-industry linkages to explore the benefits of linkage to national economies and industry, rather than to the research undertaken in universities (as discussed in 2.2.2). In identifying that there is an *exchange* of benefits from linkages the failings of the linear model of innovation are emphasised. This encourages the researcher of university-industry linkages to study linkages as a two way, or interactive, mechanisms rather than just a one way flow from universities to industry. The relative contribution by those involved will vary upon the level of linkage activity, yet there will always be some exchange between university and industry researchers.

When examining instances of linkage in this study, linkages will be viewed as a mechanism for such exchanges with both university and industry researchers contributing to, and gaining from, all linkage mechanisms and it is this thinking that shall underpin the analysis in this thesis.

2.3.3 Barriers to Linkage

A number of possible barriers to creating linkages between industry and universities is identified in the literature. Howells et al (1998), in their survey of university research activity in UK universities, identified the main barriers to linkage. These are displayed in table 2.3.

Table 2.3 Barriers to research linkages (Howells et al, 1998)

Rank	Barriers to establishing research linkages to industry
1	Differences in objectives
2	Work needed by industry not interesting
3	Difficulties in making contacts with relevant organisations
4	No influence on base line funding
5	Insufficient equipment and facilities
6	No influence on academic promotions
7	Delay in publications
8	IPR issues
9	HEIs not seen as reliable

The top ranked barrier echoes the findings of other researchers (such as Lee, 1996 and Jones-Evans et al, 1999) who indicate that a key barrier is often the difference in objectives of university and industry and a lack of interest on the part of academia in the work of relevance to industry (these characteristics and possible routes to overcome them, are discussed in further depth below in section 2.6). In addition to these barriers, Howells et al (1998: p. 63) also identified that the need to publish for the university Research Assessment Exercise may act as a barrier to linkage as firms may not wish results of sponsored research to become public.

2.4 Exploring What is Transferred (and How) in Linkage

To develop an in depth understanding of the process and benefits of university-industry linkage, it is necessary to look beyond the basic characteristics described in the previous section and understand what is transferred (and how) in linkage activity. Such an understanding is vital to a study seeking to explore the reasons for different attitudes and behaviour of those involved in linkage.

This section will discuss three key themes from the literature on how and what is transferred in linkage. First, the importance of informal links between university and industry is discussed. This extends the understanding of the mechanisms of linkage described in the previous section and recognises informal interactions as vital aspects in the linkage process. Second, research into the flows of knowledge between university and industry is discussed. This demonstrates the types of knowledge that are transferred between university and industry and develops the understanding of the benefits of linkage presented in the previous section. This discussion leads onto exploring the factors that can influence the types and extent of linkage in different contexts. This highlights the characteristics that may influence linkage activity in this study of oil and gas sector linkages.

2.4.1. Informal Interactions Between University and Industry

Section 2.3 has described the key routes through which linkage can occur between university and industry. These are all formal mechanisms of linkage yet research has shown that informal linkages can be as or more important than formal linkages (Rappert et al, 1999). However these linkages are often not highlighted in large scale surveys on university-industry interaction (for example, Charles and Conway, 2001; Howells et al, 1998) and as a result their importance can be underestimated.

Informal linkages are of value for two key reasons. First, they allow information and expertise to be exchanged through casual interactions and requests for information (Bozeman, 2000; Shartinger et al, 2002; Harmon et al, 1997) and second, they often form the basis of more formal instances of linkage and are the reasons for their success (Davenport et al, 1999; Faulkner and Senker, 1995a; Dill, 1990).

Davenport et. al. (1999) note that one of the major benefits of any type of linkage is the ability for actors from each organisation to be able to ‘get to know’ each other and therefore assess their mutual interests, methods of working, personalities and subsequently likelihood of linking again in the future. Small scale linkages such as university consultancy and testing or training services offer the ideal environment with which to build these relationships. Harmon et al (1997: p. 424) found that in

“the overwhelming number of cases” informal mechanisms were the basis of longer and larger research between university and industry and were often based on long term friendships.

Informal linkages are often not based around a particular research project (although some may result from formal linkage activity) and are generated and maintained through meetings at conferences, friendships and associations, industry or research area related professional organisations, chance meetings and so on (Harmon et al , 1997; Dickson, 1996). Dickson (1996) also identified these types of opportunities as vital in the promotion the professional-to-professional respect that forms the foundation of informal networks. Regular interactions between university and industry can help to create and strengthen these research networks and as a result companies using these networks can be more sensitive and reactive to new developments in science that could give rise to profitable innovations (Faulkner and Senker, 1995a).

Small and informal links between the two sectors, such as consultancy and infrequent requests for advice or opinion of contacts, help to keep industrial scientists in a network and break down barriers between the institutions (Salter et al, 2000). Such links also give direction to long term research and development objectives. As a result of this, Industrial Liaison Officers (ILOs) at universities are often active in ‘matchmaking’ between university departments and potential industry partners. Indeed only 8% of Higher Education Establishments employ no staff in this role (Charles and Conway, 2001). Other routes, such as the creation of an industrial advisory group for a particular university department (see MacKenzie and Rhys-Jones, 1985) are used to promote the build up of relationships that may lead to formal linkage.

This study builds on this literature to examine the informal interactions that occur alongside formal linkages in the oil and gas sector and assesses their importance.

2.4.2 The Study of 'Knowledge Flows'

Examining what type of knowledge is transferred in linkages can add further depth to the understanding of the processes and benefits of university-industry interactions and provide a more theoretical basis for exploring university-industry linkages.

The importance of tacit knowledge (Polyani, 1967) – the techniques and skills embedded within researchers and associated with the use of technologies – is acknowledged as important in the understanding and utilisation of formal knowledge (Vincenti, 1990). Tacit knowledge cannot be transferred in written form (Faulkner and Senker, 1995a) and therefore requires direct personal interactions between researchers to facilitate its transfer. This reminds us again that the actions of, and relationships between, those involved in technology transfer are of vital importance to linkage and that informal interactions (such as phone calls and informal meetings) are fundamental to the effective flow of knowledge between university and industry.

Research by Gibbons and Johnston (1974), Faulkner and Senker (1995a) and Rappert et al (1999) sought to extend and enhance the understanding of the transfer of knowledge and expertise between university and industry through focussing upon knowledge flows to better understand the role of public sector research in innovation. Faulkner and Senker (1995a) examined public-private sector research linkages in biotechnology, parallel computing and ceramics. They conceptualised knowledge flows between public sector and industry research in terms of scientific and technological inputs (STI) and formulated a composite typology of innovation knowledge which breaks down knowledge into fifteen different types, ranging from 'properties of materials' to 'practical experience'. These are outlined in table 2.4. This key aspect of analysing the *knowledge flows* filled the gap left by other studies and provided a much enriched view of the inputs to innovation. These STIs were examined further in terms of sources (e.g. university or internal firm research etc), impacts (relative importance of particular knowledge types from different sources) and the channels (methods of transfer of knowledge, e.g. literature, contacts or recruitment) of knowledge flows in industry-public sector research relations.

Table 2.4 Composite Typology of Innovation Knowledge (Faulkner and Senker, 1995a, p.219)

Knowledge Type	Description
SCIENTIFIC and ENGINEERING THEORY	
PROPERTIES OF MATERIALS	An understanding of the properties of natural and artificial materials
DESIGN CRITERIA AND SPECIFICATIONS	An understanding of user requirements, the selection of concept designs, and design elaboration
DESIGN CONCEPTS	An understanding of fundamental operating principles and creativity in the design process
DESIGN INSTRUMENTALITIES	The ability to follow structural procedures (e.g., to decompose a problem into subproblems) and judgmental skills
DESIGN COMPETENCE	Skills in all aspects of design (general and specific)
PRACTICAL EXPERIENCE	Previous work experience (inside or outside this firm)
EXPERIMENTAL and TEST PROCEDURES	An understanding of accepted ways of setting up experiments and tests
RESEARCH INSTRUMENTALITIES	The utilisation of experimental techniques and equipment, and the interpretation of test and experimental results
RESEARCH AND DEVELOPMENT COMPETENCE	Skills in managing and organising research and development (both in general and specific)

This research found that universities contribute significantly in the two areas – scanning the research frontier and underpinning knowledge – reflecting the fact that in general, “industry conducts primarily development work, with a small element of (mostly applied) research, whilst academic and government laboratories primarily conduct basic research, with a small element of development work” (Faulkner, 1997: p.186).

2.4.3 Cross-Sector Differences in the Extent and Types of Linkage

Faulkner and Senker’s (1995a, 1995b) research on the flows of knowledge into innovating firms identified clear cross sector differences in the extent of formal linkage activity, the relative significance of university knowledge and information and in the particular knowledge contributions to industry. These findings are echoed by Schartinger et al (2002) whose study focused upon the ‘variation in knowledge interactions’ between university and industry across a range of sectors. Bozeman’s (2000) model to investigate methods of assessing effectiveness of technology transfer

also highlights reasons (including the characteristics of those involved in linkage) for differing levels of interaction between university and industry. Exploring these differences is useful in understanding why linkages are more or less likely to occur in particular settings. The study of linkages in this thesis focuses on one particular sector but the characteristics that are identified by these researchers are pertinent to understanding the reasons behind the levels of linkage that are identified.

Faulkner and Senker's (1995b) analysis of the reasons for this diversity between sectors identified four distinct factors relating to the particular industry sector, the characteristics of the firms involved, the particular characteristics of technologies and university-related factors. These factors (to be outlined in turn below) are interrelated and complex and as a result do not lend themselves to a simple explanatory model of the reasons for diversity in extent of linkage. However they do identify characteristics that could affect linkage activity in the oil and gas sector.

Industry Sectors where innovation could be described as 'knowledge led', that is, where product development relies strongly on research activities (such as in the pharmaceutical industry) appear to have stronger links with universities (Faulkner and Senker, 1995b: p.101). Schartinger et. al. (2002: p.307) echo these findings, indicating that "those sectors which have a high intensity of R&D, an orientation on radical innovations and, consequently a high share of knowledge inputs on their production function, are expected to use knowledge inputs [from universities] more than others [who are more incrementally innovative and customer focused]".

In other sectors, innovation may be more 'circular' in nature, with strong feedback between end-users and the suppliers in the development of new products. von Hippel (1988) and Rappert et. al. (1999) have highlighted certain sectors where the importance of end user interactions is much greater than those with the science base. As a result linkages with university are likely to be less common in these sectors (unless the end user is the university, as noted by both Faulkner and Senker (1995a) in the field of parallel computing, and Rappert et. al. (1999) in the field of scientific instruments).

The oil and gas sector in the North Sea could not be described as knowledge-led in the same way as the pharmaceutical sector, yet recent developments (as outlined in chapter one) could suggest that as oil fields become more marginal, more new scientific knowledge may be required to guide the development of oil fields in the future. This suggests that new knowledge from universities in the geosciences and engineering could become increasingly important. This study does not seek to track trends in linkage, but may be useful as a benchmark study for future research in this area.

Firm-Related Factors have been found to directly affect the linkages between universities and industry (Harmon et al, 1997; Corsten, 1987). Larger linkages occur mainly with larger firms as a result of the resources such firms can put into long term research. The lack of resources in small and medium sized enterprises (SMEs) means that they have more difficulty linking with universities. Corsten (1987) and Shane (2002) in their studies focusing on linkages involving small firms have both indicated that the likelihood of linkage increases dramatically with the size of the firm.

Faulkner and Senker (1995b: p.101) also note that small firms also may lack the ability to be involved in informal networking activities (as a result of the limited personnel resources) leaving them likely to lose out on opportunities to build up the contacts that can lead to formal linkages. This is a problem for all firms, but is also stressed by Mowery (1998: p.42) as a particular difficulty for smaller organisations. SMEs often require quick solutions due to their tight time and budgetary constraints – a mechanism that is less suited to university research methods. The culture of the larger firms may be more appropriate for linkage as large scale industrial labs can be closer to university departments, where approaches to solving problems rather than ready made solutions are required (Corsten, 1987). In addition, Roessner (1993) indicates that interest in forming links with external organisations increases as the size of a firm's internal R&D capability decreases (or vice versa). Lee (1996) also suggests that academics may prefer to link with larger firms because they are likely to receive greater benefits in terms of teaching and research assistance.

Faulkner and Senker (1995b) describe firms as being either ‘extrovert’ or ‘introvert’ with regard to the external research community. With companies of the same size and in the same sector demonstrating different ‘propensities’ to linkage. Their research indicated that this is related to a number of reasons including current profit levels, recruitment policy, company culture and the attitude and behaviour of staff (a factor that is explored further in section 2.5 below).

Technology Related Factors also affect the character and extent of university-industry linkages. Faulkner and Senker (1995b) identified that researchers in new and emerging fields (such as biotechnology), or areas in which new technologies are emerging, are more likely to form linkages with universities. In addition, the general character of the technology may also influence the extent of linkage – with university-industry linkage being more likely in science based technologies, or technologies that are perceived to be radical, than in technologies that are process or product based.

As described in chapter one, the oil and gas sector comprises a broad range of firm types (including small firms and large multinational companies) and incorporates the engineering and geoscience sectors. This study explores the influence of these on the extent of linkages in this sector.

University Related Factors, in particular the availability of expertise within universities, has a direct bearing on the scope for university-industry interaction in any one field. In different fields the nature of the university expertise may not be deemed appropriate or may be too theoretical for industry to want to create linkages. For example, Faulkner and Senker (1995a) found biotechnology researchers linked frequently with university, whereas in the engineering ceramics field there was very little academic research and therefore few instances of linkage. Schartinger et. al. (2002) also note that the technological proximity between scientific field and industry sector as a key determinant in the extent of linkages.

In addition the university as a whole, separate departments and individual researchers all influence the nature of a university-industry research linkage. These factors will

not only influence the desire to create linkages but also place limits (or otherwise) on the potential strength of those linkages (Butler and Birley, 1998). The specific nature of universities and individual departments reflect the availability of the particular expertise within universities. Ex-polytechnic universities traditionally have strong ties with industry and these can lead to strong research linkages. Indeed, Charles and Conway (2001: p.62) note that the leading 'post 1992' universities report higher consultancy income than the average 'pre-1992' universities.

These university related factors indicate areas which this study must address. However, the factors relating to university departments also directly affect those operating within them and therefore it is important to assess how these factors may influence the attitudes, perceptions and willingness of researchers to partake in both informal and formal routes of linkage. This is the focus for the next section.

2.5 Exploring Researcher Behaviour

This section of the literature review focuses on the behaviour and attitudes of researchers involved in linkage. This is examined in two sections. First, studies that have sought to 'map' researcher behaviour and attitudes will be discussed. This will present the range of researcher perspectives that have been identified in the literature and demonstrate that some researchers will be more likely to link than others. Second, literature that has sought to *explain* the reasons behind these differences is explored – this is ultimately what this thesis focuses upon and it is from these studies that the final analysis in this thesis is developed.

This section focuses on the university researchers (rather than industry researchers) for two key reasons. First, there is a limited body of literature on industry researchers involved in university-industry linkage and second, this project (for reasons explained fully in the next chapter) focuses more upon university researchers rather than those from industry.

2.5.1 Mapping Researcher Behaviour

The literature that maps researcher behaviour in linkage begins to identify factors that influence why different researchers behave differently in linkage and why some are more likely to link than others. The attitudes and perspectives of university researchers, and their influence upon the extent of research linkages with industry, has been investigated by Lee (1996), Rahm (1994), and Campbell and Slaughter (1999). This research highlights that some researchers are likely to link with industry and keen to utilise their knowledge and expertise on industrially relevant work and others less likely to due to concerns about the perceived negative influence of commercial research requirements. Much of this body of research (e.g. Schartinger et al, 2002; and Rahm, 1994) utilises large scale survey methods and is descriptive in its analysis of university researcher behaviour and attitudes. Rahm (1994) used these methods to develop descriptive categories of 'spanning' and 'university-bound' researchers and grouped researchers into those that actively seek to forge links with industry and those who do not. Similarly, Santoro and Chakrabharti (2002) categorised the researchers who are active with industry as 'process-promoters' (sales persons of new ideas), 'experts' (those who provide the expertise and are most effective in idea generation) and 'sponsors' (those who control budgets and organisational issues) (2002: p.1177).

Other research seeking to 'map' university-industry linkages begins to look more closely at linkage and the associated behaviour of researchers. Klofsten and Jones-Evans (2000) analysed data relating to the linkage activity of university researchers by factors such as age, qualifications and university environment. This research starts to unpick the individual characteristics that may determine why linkage behaviour varies between different researchers, but does not attempt to explore these criteria in more depth through qualitative methods. In many cases (for example, Howells et al, 1998; Jones-Evans et al, 1999; Howells and Nedeva, 2003), the findings are gathered from Industrial Liaison Officers (ILOs) in the universities rather than the researchers themselves. The motivations and attitudes of the researchers may be different, or additional to, those of the ILOs (whose primary mission of is

often to generate income for the university). Therefore this type of research is valuable in describing ILO attitudes towards linkage but does not provide anything detailed on the researchers themselves. In not talking directly to researchers information is likely to be missed on their attitudes to and motivations for linkage, which can be key determinants in the success or failure of linkage

Despite this limitation, this research is valuable in highlighting factors directly related to university researchers directly affecting linkage behaviour. However, this research often does not attempt to explain in depth the reasons and factors behind this differing behaviour of researchers in their linkages with industry. This is key to developing an in depth understanding of why different researchers have these differing perspectives.

2.5.2 Understanding Researcher Behaviour

A small body of literature does seek to understand the reasons behind differences in researcher attitudes and behaviour and it is these that will be discussed in this section and upon which the final analysis of this study will build.

Using interview based methods, Butler and Birley (1998) generated findings similar the studies mentioned above and grouped researchers by levels of activity and interest in linkage (e.g. 'enthusiastic researchers', 'disinterested', those who 'held the academic high ground'). Butler and Birley (1998, p.102) highlighted three key areas to assist in classifying researchers attitudes: researcher perceptions of their own role as an academic in relation to technology transfer; researcher perceptions of the proper role for university research; and comments about their personal interest in their work. Although Butler and Birley did not take this research beyond classifying researchers into types, these areas of questioning signpost routes through which understanding the reasons behind researcher attitudes can be usefully examined – and these areas are key to this study of linkages.

There has been some research that has attempted to apply theory to understanding and explaining the impact different researchers can have on the extent and character

of their linkages with industry. Three key instances of this research are Bozeman et. al. (2001), Turpin (1999), and Webster (1994). These shall be described below.

Bozeman et. al. (2001) highlight the importance of personal interactions and perspectives in the shaping of research relationships between university and industry. Their research examined the skills, social networks, career history, choices and attitudes of researchers in assessing and evaluating research interactions. A model was developed centred on the scientists' career trajectories and their development, rather than simply focusing upon a particular research project. This is encapsulated by what they describe as 'Scientific and Technological Human Capital' (S&THC) (Bozeman et al, 2001), which includes the skills and knowledge of the researcher, the social capital of the researcher (e.g. networks and connections) and their life cycle (describing the development in the first two categories over time). They proposed that university-industry linkages can be evaluated in terms of the development of the S&THC of the individuals working on these projects. This approach highlights a range of factors that can influence the behaviour of individuals within a project linking university and industry. Unfortunately, the model has yet to be applied to empirical data, so its success or failure in exploring research interactions cannot be fully evaluated.

Turpin (1999) examined the researcher and the university department within which s/he is situated when undertaking linkages between university and industry. Turpin utilised Douglas's grid-group theory (1982) to investigate the reasons why different university departments or disciplines have appeared to be more conducive to interaction with industry or produce different types of university-industry relationships. Turpin suggested that the changing university environment, in which the influence of commercial and entrepreneurial pressures is increasing, forces a cultural change on the traditional practices of the university department and researcher. Departments and individuals respond in different ways to these pressures, and this may result in an environment that moves towards a 'hierarchical' structure which manages, supports and promotes commercially-oriented research and industry interaction. Conversely, Turpin indicated that the same pressures may reinforce the

traditional 'egalitarian' values of belief in scientific excellence (free dissemination of research, peer review and a resistance towards the influence of market forces) and result a very non-commercially orientated department. Clearly, these developments will make departments and individuals more or less likely to form links with industry. Similar to Bozeman et al (2001) above, this work also indicated that career trajectories can be important in understanding attitudes.

Webster (1994) conducted empirical research into the investigation of long-term research alliances (joint research centres) between university and industry, exploring the individual characteristics of the researchers and their institutional environment. Webster's research describes the process of research agenda construction by researchers within these settings through examining the structural and social contexts of the linkage.

Webster suggested that the interplay of the following three linked "dimensions of collaboration" shape a researcher's work:

- 'Institutional features' (the social and cognitive context within which the linkage is located, e.g. type of department, department research strategy, levels of interaction, specificity of research foci, type of deliverables, definition of success)
- 'agency of researchers' (e.g. what they regard as the most appropriate ways of defending their interests given the context, how they enlist sponsors/allies, and how they direct research); and
- the 'rhetoric or discourse' of the researchers (how they defend their course and justify and make sense of their actions) (summary of Webster 1994, p.130).

Through this approach, Webster stressed the influence of interactions between the characteristics of the researcher and their departmental research environment upon the behaviour and attitudes of the researchers involved and subsequently upon the nature of the research work itself. Similar to Faulkner and Senker's (1995b)

discussion of cross-sector diversity in extent of university-industry research linkages, it does not provide a simple 'tool' but highlights key determinants and gives insights into "how we can understand the ways in which a changing context creates opportunities for [researchers] to both redefine and legitimate the research they pursue" (Webster, 1994: p.140).

Webster's exploration of this interplay of dimensions creates a route through which the attitudes and perspectives of researchers can be examined. This work, combined with findings from Turpin (1990) and Bozeman et al (2001) and findings from the research in this thesis, are used in Chapter 7 to develop a framework to allow the motivations and behaviour of university researchers that are the subject of this thesis to be examined.

2.6 Making Linkage Work

This final section discusses the factors that influence the success or effectiveness of university-industry linkages and barriers to this success. This discussion will demonstrate that many of the factors noted in the literature as being determinants of success in linkage are closely related to the key factors that have been highlighted in the previous sections of this chapter – i.e. success is linked to individual attitudes, to their interpersonal relationships and to their institutions. However, before this process is commenced, it is important to make some comments on what exactly constitutes a successful or 'effective' research linkage.

Bozeman (2000) stresses that effectiveness can have different meanings in different contexts – including "market impacts, political impacts, impacts on personnel involved, impacts on resources available for other purposes and other scientific and technical objectives" (Bozeman, 2000: p.628). These dimensions may determine the 'effectiveness' of a transfer, with the linkage mechanism used and the extent of linkage between university and industry an important factor in determining which (or how many) of these dimensions are viewed as important by those involved in linkage. These different interpretations of what constitutes effective linkage can lead to different impressions of what constitutes effective transfer from those involved.

What is seen as effective by one partner in linkage may not be viewed as such by another. This suggests that effective understanding and communication, good management and trust between partners is important in ensuring reaching mutually 'effective' linkages.

In this section I shall investigate the factors that influence the 'effectiveness' or success of any university-industry linkage in three areas encompassing: organisational culture; management of interactions; and trust between partners in interaction.

2.6.1 Cultural Factors

The differing working practices and goals of university and industry are often deemed to give rise to a 'culture clash' (e.g. Jones-Evans et al, 1999; Howells et al, 1998). The mixing of these different cultures can result "in conflicting attitudes to the management of the project [which] combine to form a barrier between the two partners" (Davenport et al, 1999). Indeed Geisler (1997), in a review of the literature on linkages, suggests that although there is much evidence of university and industry working effectively together the differences in the culture of the two organisations can make linkage a problematic and difficult exercise.

Culture "constitut[es] the way of life of [an organisation] and this will include codes of manners, language, values, norms of behaviour and systems of belief"(Jary and Jary, 1995; p.139), it "has a powerful influence on everything in the organisation" (Deal and Kennedy, 1982). As a result the particular characteristics of an individual organisation will have a great influence upon how it will interact with others.

University and industry cultures are based around different sets of aims, attitudes and norms of behaviour and consequently working together may prove troublesome (Lee, 1996; Gielser, 1997; McHenry, 1990). Corsten (1987: p.59) notes that commonly mentioned obstacles of linkage with universities are the different systems of values, academics' inclination toward perfectionism, hostility to compromise, lack of regard for deadlines and confidentiality problems. Lee (1996: p.861) suggests that university researchers often fear entering into a 'Faustian bargain' of increased

funding allied to restrictions on publishing and knowledge dissemination when linking with industry. Rahm (1994) also noted, in studies of university researchers' perceptions of linkage, that many individual university researchers were resistant to linkage for these reasons.

These different attitudes and aims of universities and industry stem from their traditionally different orientations. The academic community operates in an environment with an ethos of open-ended research and wide intellectual horizons (Lee and Gaertner, 1994). Academics maintain or increase their standing in the community through the publication of research papers, have a degree of freedom about what they research, and are free from commercial deadlines (although increasingly academics are pressured to regularly produce research to maintain departmental status and research council and government funding). Both Senker (1990) and Howells et al (1998) found that the major barriers to linkage for university researchers were the different research objectives of industry, that industrially related research was of reduced academic relevance and in many cases simply was not interesting to them (see 2.3.3).

Therefore, researchers wishing to make the linkages between university and industry have potentially significant cultural, and related structural, barriers to overcome. Routes through which these barriers can be broken down are explored in the next section.

2.6.2 Mutual Trust and Understanding

Successful research linkages are extremely difficult to achieve without building up elements of trust, mutual respect and co-operation between the researchers involved (McHenry, 1990). Undertaking any linkage with parties outside a particular community (e.g. between a group of university researchers and industrial scientists) can be less successful than those undertaking linkages within one community and create cultural differences. In a study of university-industry linkages in the biotechnology industry, Zucker et al (1996) found that "distrust is one of the major costs involved in transacting across organisational boundaries" (p.108). However,

where high levels of inter-personal trust are built up between scientists and managers in the collaborative groups, it has been seen to greatly aid the transfer of knowledge and increase the chances of success (Dodgson, 1993).

Senker (1990) proposed four key rules for successful linkage: management, finding out what each side wants, friendship and effort. These rules stress the need for trust and respect between partners. In treating fellow researchers involved in linkage as friends, trust and understanding will build up between partners and reinforce the link, enabling both sides to get what they want out of the interaction and to understand and accommodate the needs of each other. Davenport et al (1999) also strongly note the importance of trust and, more significantly, that in the case of repeat linkages between university and industry trust evolved and was enhanced between partners. Consequently, they recommend that to gain the full benefit out of linkages, long term relationships should be aimed for.

In the discussion of the range of different mechanisms through which university and industry can link (see 2.4), it was indicated that small scale linkages can lead to larger forms of linkage in the future. This 'step-wise' build up of linkages is facilitated and led by a build up of trust and understanding between the research partners (Faulkner and Senker, 1995a). Senker (1990: p.55) notes that "a great deal of mutual suspicion and antagonism was displayed" between university and industry partners in research. Yet through getting to know each other through smaller levels of linkage, trust, understanding and co-operation can be built up between partners – ensuring that suspicion and antagonism is avoided (Dill, 1990; Harmon et al, 1997). Indeed it has been noted that "large scale linkages have a better chance of success if they have been preceded by a history of small scale informal interactions...and friendly relations" (Faulkner and Senker, 1995a: p.234)

Dodgson (1993) stresses the importance of building up inter-organisational trust alongside the inter-personal trust built up between individuals to ensure long term success. Trust can become embedded in inter-organisational culture if activities are created ensure that the linkages go beyond a small number of direct contacts. Managing this process is, of course, not simple and Dodgson again stresses the

importance of long term links. Dill (1990) indicates that the geographical proximity of sponsors can be a critical factor in maintaining trust within these links and making linkages succeed.

Interpersonal relationships between researchers from university and industry are therefore important in the development of successful linkages. Faulkner and Senker (1995a, 1995b) highlight this importance by suggesting that, in taking steps to forge linkages between university and industry, organisations should be careful to avoid forcing linkages upon researchers 'top down'. They suggest it may be more productive to produce communication points or opportunities for people to meet and exchange ideas and information. Intermediary agencies bringing researchers together (be they university ILOs, company management or individuals) are therefore better using this 'dating agency' approach than forcing linkages along the lines of a 'marriage broker' (Faulkner and Senker, 1995b: p.106).

2.6.3 'Championing' the University-Industry Interaction

The presence of individuals or 'research champions' in research linkages has been identified as a key element in their success (Senker, 1990; Hicks, 1993). Rahm (1994) and Santoro and Chakrabarti (2002) identified research champions from their studies of university-industry linkages, noting in particular the positive effect upon interactions that arises when individual researchers have frequent personal (often informal) interactions with their external partners (Santoro and Chakrabarti, 2002: p.1167). Research champions, as a result of their enthusiasm for linkage (in general or in a particular case), work to obtain a clear understanding of the goals, methods and nature of those involved and act to reassess these both before and during the entire linkage. The importance of the involvement of a familiar champion who understands a particular relationship between university and industry is reinforced by the findings of Harmon et al (1997: p.428) who found that approximately 75% of research linkages were based on previous interactions between partners.

Giesler et al (1990) noted that projects and centres can become too dependent upon an individual and their personal contacts, particularly if these 'champions' move on,

and that continuing success is more likely to occur through the implementation of solid management structures to ensure that good relations are maintained and continue to be created. Without this the trust and goodwill that has been built up by 'project champions' will be lost entirely if they leave. Webster (1994) and Dodgson (1993) have noted the frustrations of university researchers (who are more likely to remain in long term positions within their institution) finding it difficult to continue research projects with different industry contacts as research directions may be changed and new relationships have to be built up.

To address these longer term issues some researchers of university-industry linkages have promoted the idea of utilising an intermediary agent in university-industry interactions (e.g. Bloedon and Stokes, 1994). This actor takes the role of a research champion – but is employed directly to do this rather than taking on the role from within a particular linkage. Most universities now have industrial liaison officers (ILOs) (Charles and Conway, 2001) to act as intermediaries in the linkage process. However, the exact remit of these actors varies greatly (Jones-Evans et al, 1999), from legal assistance in the creation of research contracts, through to assisting in the management of linkages and in some cases actively advertising the services of university researchers to industry. In other cases staff have been specifically employed by larger linkages to act as an intermediary agent or project manager (Bloeden and Stokes, 1994). However, the importance of trust in relationships may mean that bringing an 'agent' in to manage a research linkage between university and industry may not be as effective as an internal 'champion'.

This section has discussed some key barriers that have been identified in the literature and steps that can be taken to overcome these and increase the chances of success in linkage. It was noted that there can be different interpretations of what constitutes an effective linkage, and that these may depend on the individuals concerned. Again the importance of the individual researchers has been indicated to be central to the linkage process. Effective communication, understanding and the build up of trust between researchers has been shown to assist in overcoming cultural barriers between university and industry. In addition, the presence of a research

champion (in particular from within a particular instance of linkage) can facilitate this process.

2.7 Conclusions

This discussion of the literature on university-industry linkages has revealed a number of key themes that will guide this study of oil and gas sector linkages. Much of the research on university-industry linkages has been identified as lacking a strong theoretical background and as a result much has been merely descriptive of the nature and extent of linkage. Yet this research is useful in providing an overview of the types and levels of linkage occurring between all universities and industry across all sectors from which further studies of university-industry linkage can be compared and contrasted.

Findings from innovation studies have indicated that university-industry linkage should be viewed not as a linear or one way process but as a two-way, or interactive, flow of knowledge between university and industry. Evidence on the range of benefits to both universities and industry confirms this understanding of linkage with both sides having the potential to gain a range of different benefits from linkage.

Informal contacts and interactions between university and industry researchers have been identified as important in overcoming the barriers to linkage activity. They are also important in forming the basis for the generation of formal linkages and in the transfer of, in particular, tacit knowledge that may not be exchanged through formal mechanisms.

The research literature identifies a range of factors that can explain differences in the extent of linkage across sectors such as firm size, factors relating to the state of knowledge in universities, the nature of the technologies and the characteristics of the sector concerned. In addition, the individuals active in the linkage process have been demonstrated to be of vital importance to the success of linkage activity. Individuals play a key role in managing the linkage process and overcoming the cultural and structural barriers (such as research deadlines and knowledge dissemination / privacy

issues) that can occur between university and industry. Individuals are the route through which crucial personal and institutional trust, respect and understanding develops (or not) between partners in linkage.

When these key individual-related features of successful linkage are viewed alongside the importance that is placed over informal interactions between those involved in linkage, it is clear that understanding the attitudes and behaviour of the individuals active in linkage is a fundamental part of any understanding of university-industry linkage. A small number of studies have been shown to indicate routes through which these factors can be explored and analysed.

This study will build upon these findings from the literature in three key ways. First, by investigating the extent and types of linkage occurring in the North Sea oil and gas sector (a sector in which there has been little research undertaken in the field of university-industry linkages), findings can be compared to university-industry linkages as a whole in the UK to give an assessment of activity relative to other sectors.

Second, the research will explore the barriers and benefits of university-industry research linkage in the oil and gas sector, again comparing and contrasting to findings in the literature, to assess if universities and industry are gaining similar benefits and coming up against similar obstacles to linkage in other sectors. The literature indicates that informal linkages can be a key route for the transfer of knowledge between university and industry and act as the foundation for successful formal linkages and as a result this study will pay particular attention to the importance of informal linkages in this sector.

Third, this research seeks to add to the small number of studies that have used more analytical (as opposed to descriptive) methods to explore linkages through the development of a framework for understanding and explaining the reasons behind the different behaviour of the university researchers investigated in this study. The literature (in particular Webster, 1994; Bozeman et al, 2001 and Turpin, 1999) indicates that study of the behaviour of researchers involved in linkage should focus

on factors relating to the researchers' institutional environment, social/informal networks, career history, attitudes, responses to changes in environment, their choices of projects or deliverables and how they defend or explain their actions. The development of a framework seeking to incorporate these elements will be facilitated by the in-depth exploration of researchers' perceptions, motivations and attitudes to linkage activity, in addition to an analysis of their perceptions of benefits and barriers to linkage.

2.7.1 Aims and Research Questions

The key aim of the study is to explore university-industry research linkages in the oil and gas sector. This aim will be met by addressing the following research questions.

1. What is the nature and extent of research linkages between universities and the oil and gas industry?
2. What are the benefits of, and barriers to, linkage in this sector?
3. How do factors pertaining to individual researchers and their institutional context influence the linkage process?
4. What can be learned about good practice in linkage in the sector and in university-industry linkage in general?

2.7.2 Linkages and the Oil and Gas Sector

Before embarking on the rest of the thesis it is important to reflect on the implications of the literature for understanding linkage in the oil and gas industry. In particular, these relate to the types of interaction that may be occurring between university and industry and the level of communication and understanding that may exist between the two potential partners.

First, as indicated in chapter one, the industry includes a range of technologies, from engineering to geoscience, and a range of different types of companies. These differences may have implications for the nature of linkages in the oil and gas sector.

The SME and contractor/service firms are likely to have relatively small budgets for R&D and will be focused on contract based short term projects. These companies are also more likely to be working in engineering related technologies and as a result of these two factors university interaction with these firms is likely to not only be short term but also be of a product orientated nature. However, the multinational oil firms' research interests will revolve more around the geosciences and therefore potentially be closer to university research practice in this field. This, along with the sizeable funds that they have for R&D as large companies, means that they are likely to create larger and more long term linkages with universities.

The creation of industry related university departments suggests that both formal and informal linkages between university and industry are strong in this sector. In addition to this, the concentration of the industry in Aberdeen along with a number of these oil-focused departments, suggests that there are many opportunities for the creation and maintenance of networks of local contacts. Training may prove to be a key role for the specialist departments universities to meet the demand for staff that the industry needs in Aberdeen. However, the issues around the lack of trust in the industry and the suggestion that there is not enough awareness of the each other's capabilities by both university and industry researchers in the sector (see chapter one) may mean that the relationship between industry and university may not be as healthy as could be expected.

3. Methods

3.1 Introduction

This chapter describes the methods used to gather and analyse the data for this study. The exploratory nature of this research project meant that the research focus, and therefore research design, shifted over the duration of the study. This is a common feature of social science research in which both the research and the researcher develop over the course of the research (Janesick, 2001; Phillips and Pugh, 1994). In the first section of this chapter I outline the development of my research and the factors and events that shaped the research process and the eventual research focus. The chapter then explicates the methods used to gather and analyse the data and reflects upon the implications of using these methods. Reflections on the research process as a whole, including ways in which it could be improved, are then presented.

The research questions described at the end of the last chapter describe three key themes in the exploration of university-industry linkages: the types and extent of mechanisms of linkage; the benefits and barriers to linkage; and the individual factors that influence linkage. These three themes are carried through the data collection and analysis.

3.2 An Evolving Research Process

I initially took on the PhD as a CASE studentship. Edinburgh University offered this with a not-for-profit oil industry related organisation – the Centre for Marine and Petroleum Technologies (CMPT). The broad aim of the project was to investigate the nature of research collaborations or linkages within the sector, encompassing both company-company and company-university linkages, and it was to be based partly in the CMPT's offices. I was attracted to this project as it gave me the opportunity to continue my postgraduate studies (after undertaking an MSc) alongside gaining experience working in a business environment. In particular I was attracted to the opportunity to investigate the transfer and use of university research in an industrial context.

Unfortunately, the economic situation in the oil industry at the time when I was commencing my PhD meant the CMPT had begun a process of winding its operation down and, as a result, the CASE studentship was withdrawn. This was disappointing as it meant that a direct link to the industry was lost from the project. To enable the project to continue, it was converted to a normal ESRC studentship..

In initial stages of the research design I drew heavily upon the original research proposal for the CASE studentship. This produced a research design within which I intended to utilise Faulkner's (1995) 'Composite Typology of Innovation Knowledge' (which was in the original proposal) to examine instances of university-industry research linkages as 'case studies'. It was intended at this stage that this would involve interviewing representatives from both 'sides' of large scale 'joint projects' involving university and industry researchers and examining their perceptions of the knowledge flows into the projects from different sources. These could be compared within a project and together with data on the barriers, benefits and strategies for making contact between partners would generate an in depth understanding of the nature of this form of linkages in this sector. Scoping interviews with university respondents had suggested that it would be possible to find instances of joint projects in the sector. I had hoped to cover a range of different projects encompassing different company types (operating companies, service companies and SMEs), technological areas (earth sciences and engineering) and types of university (ancient universities and modern 'post-1992' universities). This could only be done with a purposive sampling method to ensure the desired range of linkages was fully covered. I chose to do this through contacting university respondents in the first instance as I felt these would be more receptive and sympathetic to a PhD student and then use these contacts to pursue industry contacts subsequently.

The research focus and design evolved in the course of the fieldwork. After a number of interviews, it became evident that projects with a significant contribution (in terms of staffing *and* resources) from the industrial partners were lower in number

than I had expected. Most of the respondents were indicating that the vast majority of linkages that were undertaken were in the form of sponsored research, rather than joint projects. Consequently, as the project developed the research began to focus predominantly upon these 'sponsored' projects alongside the other smaller-scale forms of linkage (sponsored PhDs, sponsored posts, short-term consultancy projects etc) all of which were centred on the university rather than jointly run by the university and industry. This meant that, as I was focusing upon projects that principally the university researchers were conducting, these university respondents were providing richer and more interesting data than the industry respondents.

It also emerged that the use of the composite typology of innovation knowledge with the university-industry projects was somewhat inappropriate as almost all the knowledge inputs were coming from the university researchers. As a result, the tool (which in any case was very difficult to use, as most of the categories had to be explained to respondents to enable understanding) was providing significantly less interesting data than the other aspects of the interviewing which focused upon the nature of the relationships between university and industry research, the benefits of linkage and the barriers to building linkages.

As the research was shifting in this direction, a research interview at a major oil firm resulted in the opportunity to develop my research further in the direction of understanding the range of linkages that the university researchers were providing with the industry. The industry contact was interested in sponsoring a postal survey of university researchers involved with oil companies and offered to fund me to undertake this as a piece of consultancy work. The areas that the contact wished to investigate were the themes that were providing interesting data from my interviews, namely the ways of (and barriers to) gaining funding from industry, the range and types of projects that university researchers worked upon and the benefits of these linkages. In addition, I was free to use the findings in my final thesis. This gave me an ideal opportunity to contextualise my in depth findings from interviews with more general findings from a wider population.

The survey confirmed my findings from interviews, that the majority of linkages were in the form of sponsored research, and pushed further my shift in research focus away from attempting to study joint projects to an examination of the sponsorship of university research in the oil and gas related sector. It was as a result of these findings that the research was subsequently focused principally upon the university researchers rather than on both the industry and university figures symmetrically. My early interviews encompassed all the areas that I wished to maintain focus upon and, in the latter stages of my interviews, I dropped the use of the composite typology entirely. In this way the thesis came to develop an understanding of the industrial funding of university research projects in the oil and gas sector from the viewpoint primarily of the university researchers involved, but informed by contact with industrial sponsors.

This refocusing resulted in two major changes from the initial set of research questions. First, as a result of the shift to the academics, the systematic examination of the different company types in the sector and their interactions with academia was replaced by a more open exploration of diversity in university-industry interaction. Second, the use of the composite typology of innovation knowledge was removed from the research as it became redundant. These shifts in the research design resulted in a revised set of research questions, as outlined in section 2.7.1.

3.3 Research Design

Two key methods were used to collect data – qualitative interviewing and a self-completion survey questionnaire. The interviewing was undertaken throughout the data collection process, evolving its focus as outlined in 3.2 above, whilst the survey was conducted in parallel during the ‘middle third’ of the fieldwork.

The qualitative interviews with university and industry respondents enabled the collection of in depth data on the perspectives, experiences and practices of researchers involved in university-industry linkages. As described above, the self-completion survey was funded by an oil company and was instigated as a result of a research interview that was part of this study. This was an opportunity to expand the

dimensions of the research project and gain more quantitative data on the behaviour, practices and opinions of the university researchers. The postal survey was used primarily to place the qualitative interview findings into a wider context and, by doing so, helped to assess the generality of the findings across the sector as a whole. Conducting the survey alongside the interviews strengthened the research in three key ways, through triangulating data (Denzin, 1978), locating further respondents (Hammersley, 1996) and obtaining additional data on particular aspects of the research area (Bryman, 2001). These are discussed in detail below.

The survey aligned the research more closely to the perspectives of the group of university respondents as this was the focus of the sponsor's interest. To similarly access the industry respondents through a self-completion survey would have required the design and implementation of an additional survey which the sponsors were unwilling to fund. I had concerns over the additional length of time it would take to conduct such a survey with industry respondents and the quality of data that it would produce. Access to the potential respondents in the oil industry would have caused problems as it would have proven difficult to locate an appropriate sample group from the oil industry employees due to the limited amount of time most devote to this sort of work. The interviews had shown that the vast majority of industry contacts undertook work with universities as a small part of their job remit, or even as an outside 'hobby', and therefore enquiries to companies for contacts for a survey may have missed many potential respondents.

The use of mixed methods in social research can be both "feasible and desirable" (Bryman, 2001: p.446), but is not an approach that will inevitably prove to be superior to the utilisation of a single method. Multi-strategy research still has to remain competently designed and conducted and be appropriate to the research questions and research area that is being studied. An increase in the volume and types of data gained throughout a project is not always a 'good thing' and will not provide greater or superior insights if the research is not well designed (Bryman, 2001). Nonetheless, research undertaken through mixed methods can have a number of advantages over single method research. Hammersley (1996) describes three

‘approaches’ to multi-strategy research and their associated rationales. These are, triangulation - the use of quantitative research to corroborate qualitative research or vice versa, facilitation - the use of one research strategy to aid in the use of another (through providing hypotheses, aiding measurement or locating respondents) and complementarity - the use of different strategies to ‘dovetail’ different aspects of the research (e.g. assist in uncovering the generality of findings and study different aspects of a phenomenon). The benefits, both directly and indirectly, of all three of these approaches to multi-strategy research have assisted this research. These shall be described in turn below.

The most significant benefit of the combination of the interview and survey approaches was in the triangulation and complementarity of findings. This combination allowed the in-depth findings of a relatively small number of respondents to be compared with the more broad findings from a significantly larger number of respondents. The findings were found to be broadly consistent and mutually reinforcing with the survey results from a large number of respondents enhancing confidence in certain findings from the interviews (in particular, this related to the incidences of different linkage activities used, indications of good relationships between university researchers and industry and the importance of informal networks in gaining funding or creating linkages). The survey was not intended or expected to facilitate the later interviews yet it did result in the added benefit of locating further respondents (as described in 3.5.1 below).

Complementarity, the third of Hammersley’s criteria, was a factor in two main ways. First, the survey complemented the interviews through providing more systematic information on the full range and type of linkages that the academic researchers were undertaking with the industry. In particular, this enabled the frequency and number of different types of university-industry linkage to be assessed. The ‘complementarity’ of the survey also occurred through the responses to the questions that covered the behaviour and attitudes of the researchers. This enabled the more in-depth responses of the interviews to be compared to a wider group and to suggest the generality of the responses across university researchers in the oil and gas sector.

This echoes Silverman (2000) who argued that some quantification of findings from qualitative research can often help to uncover the generality of the phenomena being described.

3.3.1 Research Design: Why Interviews?

Understanding the attitudes, experiences and perspectives of (in particular university based) researchers and managers working in research linkages in the oil and gas industry was central to this project. To explore these criteria, a number of methods of data collection are available to the social science researcher. Direct observation is a method commonly employed by researchers seeking a detailed understanding of a particular setting or process (Sanger, 1996). This method has the advantage of allowing interactions between respondents to be studied at close hand with a “lack of artificiality” (Robson, 1993: p.191). In addition, through extensive examination of projects in this study, it would allow a deep understanding of the technology involved, enable in depth assessments of the research interaction at different levels of seniority of researcher, and allow a range of interactions between partners in linkage to be witnessed directly. However, this method is not only time consuming for the researcher, but also potentially intrusive for the participant (Agar, 1995). It was felt that people working in a pressurised and competitive environment such as the oil and gas industry would be unwilling to allow a doctoral researcher access to all their movements and interactions, particularly if they knew that the researcher might also be carrying out similar fieldwork with their competitors. In addition, the process is very time consuming and would only allow a small number of cases to be examined. As a result of these limitations, plus the need to generate comparative data on different linkage mechanisms, and the requirement to collect data on attitudes and perceptions of linkage activity, an interview-based methodology was chosen as the most suitable.

Interviews are one of the most commonly used and widely accepted methods for gathering data in the social sciences (Baker, 1997). In particular, semi-structured interviewing methods are used to explore informants’ attitudes and perceptions around a focused set of questions. Semi-structured interviewing of this type provides

an environment within which the researcher can “understand the reasons for decisions which research participants have taken, or to understand the reasons for their attitudes and opinions” (Saunders et al, 1997: pp.214-215). The approach also allows opportunities to probe for further information, to add context to data collected and to build on responses (May, 1997). In addition, this approach “affords the interviewees an opportunity to hear themselves thinking aloud about things they may not have previously considered” (Saunders et al, 1997: p. 215). Saunders and colleagues (1997) also suggest that management figures are more likely to agree to be interviewed than to complete a questionnaire especially where the interview topic is seen to be of relevance to their own work. As the research was of direct relevance to those interviewed it was thought to be an effective method of data collection in this case.

It is important to note that interviews, although commonly referred to as a method of data collection, are more accurately described as a method of “data making” (Baker, 1997: p131) as the answers given by the respondents will be influenced by the ways in which the questions are asked. Therefore it is important to reflect on the ways in which the relationship between the interviewer and interviewee influences the interview process (May, 1997). This and other related themes, and their implications, are outlined in more depth in section 3.5.2 below.

3.3.2 Research Design: Why a Postal Survey?

A key research question was to explore the nature and extent of linkage in the sector. Although this data was gathered from the informants interviewed, these in-depth findings from this small sample group could be triangulated and complemented by the use of a postal survey. The survey provided an overview of linkage activity across a much larger sample including details about different areas of technology, academic discipline, firm type and university type and so on.

May (1997) suggests that the most effective method of achieving the aim of obtaining data from a large respondent group is through a self-completion questionnaire. The self-completion questionnaire was the preferred method of research of my research

fundings and the advantages of this type of research make it well suited to this survey in two key ways. First, surveys have the advantage that a large amount of information can be gathered from the respondents with less time commitment from both the researcher and the researched than in face-to-face interviews (Neuman, 1997). Second, the standardised nature of the questions allows for comparison across respondents, making the method particularly useful for contrasting practices or perspectives across identified categories - in this case technology, academic discipline, firm type, and university type. The specific respondent group (i.e. oil and gas industry linking researchers) and widely distributed nature of the sample (from sites across the UK) determined that the questionnaire be sent to the respondents by post. The survey is an effective way of reaching a large number of participants but this is tempered by the disadvantage of an unpredictable response rate and the lack of any opportunity to probe or clarify responses. In an effort to improve response rate, researchers were contacted by phone before the questionnaire was sent and non-responses were followed up with an email reminder. Neuman (1997: p.251) suggests that "response rates may be high for a target population that is well educated and has a strong interest in the subject" making a postal survey well suited to this case. See section 3.6.2 for a details of the survey response.

3.3.3 Sampling and Generalisability

A purposive sampling approach (Bryman, 2001 Robson 1993) was utilised to locate the vast majority of the interview respondents and all of the survey respondents. Neuman (1997) has indicated that this method of sampling can be appropriate for three purposes or occasions: "First, to select unique cases that can be uniquely informative ... Second, to select members of a difficult-to-reach population ... [and third] to identify particular types of cases for in-depth investigation" (p.206). Neuman indicates that the aim of, particularly the third 'occasion', is less to generalise to a wider population but more to gain a deeper understanding of the types.

The remaining small number of other respondents were located through personal recommendations gained through the interviewing process. In addition, there were a number of survey respondents who, when returning the survey, volunteered to offer

further information if it was required. I approached some of these for interviews as I felt that they would be not only willing to agree to meet me but also be likely to provide a large amount of data as they were interested in, or valued, my research. This method of sampling is often referred to as 'snowball' sampling, and can be regarded as a particular instance of purposive sampling (Bryman, 2001) and consequently carries similar implications.

It was initially intended that the respondents were to be targeted to 'match' interview respondents from university and industry working on the same project. This was so that the impressions of the researchers from the different contexts could be compared over one project. However, due to the combination of a shifting focus onto the university researchers and difficulty in accessing industry respondents, in the majority of cases this was not possible. This resulted in a set of data that overall could not be systematically compared and contrasted from 'both sides' of particular projects. Although there are a number of instances throughout the analysis where both sides are compared, most of the interview data presented in the thesis comes from individual responses about separate projects. However, this data can be said to be indicative of the respondents' attitude, perceptions and behaviour and they were often asked in the interviews how 'typical' they felt their responses to particular questions were. Consequently, in the presentation of the analysis in Chapters 5 and 6, the full range of responses from university and industry respondents is presented wherever possible.

The sampling methods used in this study have implications on the level of generalisation of any findings. The process of generalising findings from a study such as this to a wider population is problematic for all qualitative researchers and it is often said that because of this the scope of qualitative investigations is restricted (Bryman, 2001). Researchers often use case study techniques or, in the case of this research, qualitative interviews allied to a small survey of respondents from a particular group and it is therefore difficult to generalise to other groups or settings. The strength of qualitative research is in generalising to theory rather than to a wider population - "it is the quality of the theoretical inferences that are made out of the

qualitative data that is crucial to the assessment of generalization” (Bryman 2001: p.282). However, findings must be firmly grounded in the context in which they occur so that meaningful understandings of the behaviour, values and beliefs can lead to strongly contextualised theoretical arguments.

As a result of these problems of generalisation, the findings in this thesis are not meant to be representative of a wider population. In seeking to investigate the interactions between university and industry in the oil related sector through purposively sampled qualitative interviews and survey research, the findings of the research presented in this thesis are those relating to the groups of researchers and academics at the time studied. However, the use of mixed methods adds strength to findings from this study, enabling themes that may be generalisable to sector to be identified, and these can be also be compared with research from the literature (as outlined in Chapter 2) to explore how this research may contribute to the understanding university-industry linkages in other sectors.

3.3.4 The Subjective Nature of Qualitative Research

One of the key difficulties facing the qualitative researcher is the subjective nature of both the respondents’ representations of their experiences and of the many factors that may influence their interpretations of their research. The researcher brings to any research project a preconceptions that arise out of, and are influenced by, a range of factors such as gender, race, ethnicity, social class, political preferences and academic training (Sanger, 1996). These preconceptions determine what is deemed interesting and important and what is recorded as an observation. Therefore no observations can be objective, as all observations (in the case of this research, the interview data) are coloured by the researchers personal biography.

In the case of the research undertaken for this thesis, this subjective nature of research is most apparent in the choices that were made in the development of the research (see 3.2) and in the interpretations that I make in the analysis of the data (see 3.7). My own interest in the relevance of the work of university researchers to industry and the nature of their relationship with industry partners (partly as result of

my own experiences in academia) guided the research toward this focus and favoured these factors as the focus of my study. With a different academic or career history, my focus, observations and research design choices may have been vastly different – perhaps focusing on the industry more than university. These and other social factors will have influenced the research process and it is through the use of the personal account of the development of the research process (outlined in 3.2) that I have attempted to describe to the reader the major reasons for my decision making in the research process. This reflexive approach (Vidich and Lyman, 1994) allows the reader to take account of the researcher's standpoint in assessing the research.

The participants' views, responses and reports of their experiences are also subjective. These will be influenced by a range of social and political factors and as a result the view gathered from a respondent is not a reality, merely their representation of reality (Vidich and Lyman, 1994). Subsequently, the researcher must not only consider their own subjectivity, but also observe and interpret the accounts in relation to the participant's situation. For example, throughout the research process of this thesis a range of university academics were interviewed. The academic and professional histories, as well as current working practices and pressures exerted upon these informants, are likely to have influenced their representations of their experiences. When reporting the data provided by the respondents throughout this thesis I have, where practicable and possible, provided the reader with such factors relevant to the respondent to enable the findings to be placed in context and to highlight the contingent factors shaping these findings (e.g. career history, departmental characteristics etc).

The interaction between the researcher and the informant also influences the research process. Guba and Lincoln (1994) indicate that the findings of qualitative research are created by the process of inquiry. The perception that the respondent has of the researcher will influence how they respond to the researcher and therefore the data gathered (May, 1993). In the research conducted for this thesis the relationship between myself and the informants was not uniform. Some were more reserved and guarded over the information they offered, perhaps as a result of concerns that their

successful practices may be disclosed to others through my research. Others, after I informed them of my scientific training, 'opened up' markedly and were more enthusiastic to describe their work and practices to me. This finding echoes those of Collins (2002), who describes a need for what he calls 'interactional expertise' when conducting research with scientists. This is a common problem that sociologists of science have when conducting fieldwork. Initially most researchers have no expertise in the field that they are studying but over time acquire enough to be able to 'interact' with the scientists being researched without gaining the 'contributory expertise' required to work in the field of study. By indicating my scientific experience to the respondents in my research some apparently felt that I had the 'interactional expertise' required to understand their work. Although this was not a focus of my study, for those that did extend the discussion into more scientific areas, this interaction facilitated more in-depth discussions into their interactions with their industry or university partners thus influencing the data gathered in the research.

3.4 Data Collection: Introduction

Having presented a discussion of the research design of this study the following sections will provide an in-depth description of how each stage of the research was implemented. This is an important aspect in the reporting of any qualitative research project. One of the key strengths of qualitative research is in offering in-depth reporting of social settings and research of a qualitative nature has been criticised for lacking of a full account of the choices made and methods used in the research process (Bryman, 2001). A full account of the steps taken to undertake the research project follows below (in line with the overall research design outlined above). This covers in detail the design, selection of respondents and undertaking of the interviews and the survey. It concludes with a discussion of how the analysis of these data sources was undertaken.

3.5 Data Collection: The Research Interviews

The semi-structured interviews were carried out with 30 respondents from industry and university settings. These interviews enabled research interactions in this sector

to be explored in depth. This was done by interviewing academics and industrialists in both managerial and ‘bench’ research positions. The data was collected on both managerial (or university head of department) and project-based levels on both sides of the linkages (though not generally matched). The final numbers of respondents and their ‘positions’ are indicated in table 3.1 below. These figures were not targets from the outset of the research process. In line with much qualitative research, the size of the sample was set when ‘saturation’ had been reached. Saturation is the point at which additional interviews fail to add additional insights (NCSR, 2003) and it was when this point was reached that interviews ceased. In the case of this study, the information gathered from the survey which supported interview findings on the types of linkages occurring, the attitudes of university researchers towards sponsored research and the types of barriers to linkage may have hastened this process.

Table 3.1 Range of Interview Respondents

Respondent Type	No.
Senior University Researchers/ HoD etc.	9
University Researchers	8
Senior Industry Figures	6
Industry Researchers / Junior Staff	7

Information was collected about the creation of linkages and the motivations and expectations of the researchers involved. At the managerial level, university heads of department and industrial managers were interviewed to ascertain if an understanding of expectations, motivations and technological capabilities was shared between managers and researchers. In addition, any differences in expectation and linkage of firms to linkage between the traditional university science departments and the newer specialist centres was examined.

3.5.1 Selecting Interviewees

The need to obtain a data set including a cross section of interactions between differing types of university departments, different company types and encompassing different technological types in the field, necessitated a purposive or judgmental form

of sampling (Robson, 1993; Saunders et al, 1997). In the early stages of the research process steps were taken to access respondents from a range of different university types, academic disciplines and from different types of company. This resulted in interviewing respondents from engineering and geo-science disciplines, specialist oil related departments and traditional subject based departments, 'new', 'red-brick', and 'ancient' universities and large and medium sized oil companies, large service companies and SME supplier companies.

The chosen course of action for purposively locating this range of informants in these groups is outlined as follows. First, university researchers 'linking' with the oil industry were located through web searches of university departmental websites, phone calls and email requests to specifically locate suitable informants. These respondents were asked during the interviews if they could give details of any industrial partners or sponsors they felt would be appropriate and willing to be interviewed. This enabled informants from 'both sides' of any particular interaction to be located (rather than informants from different projects) in line with the original aims of the study. This approach was chosen as it was felt that university informants would be easier to locate 'from scratch' and initially more likely than industrial contacts to give up their time to be interviewed. It was then hoped that having been recommended by their university partner, the industrialist would be more likely to grant an interview. This technique proved reasonably successful with many, but not all, industry contacts gained in this way. Other industry contacts were gained from industry websites, speculative letters and information gained from other industry interviews.

In addition to the strategy described above, the survey provided the contacts for a number of the latter interview respondents. A number of survey respondents had not only provided full answers but had offered additional data in the survey or suggested that they be approached if further information was required. A number of these respondents were subsequently approached for interviews. This group of researchers were selected to create a respondent group from a range of different universities and

departments, that is both industry focused and general departments and traditional and ex-polytechnic and ex-college universities.

Due to the prevalence of sponsored research in university-industry interaction in this sector, the majority of these interviews covered the respondents' experiences of industrially sponsored university research. However, respondents were targeted initially to access other forms of interaction. This resulted in data being gathered upon instances of sponsored posts, sponsored PhD students, TCS Schemes, university consultancy work alongside data from the industry sponsored university research projects. The shift in focus of the research to the sponsored university research project resulted in the areas principally, though not exclusively, being investigated from the viewpoint of the university researcher. The university researchers were central in the conduct of sponsored research, therefore an understanding of their practices, experiences and perspectives were central to the research.

3.5.2 The Interview Schedule

The interview schedule was designed in four parts with minor differences in emphasis and questioning to make the questioning appropriate to industry or university figures and to senior or junior informants. The first part focused upon the organisational environment of the informant and their department, covering the nature of research work undertaken, the expectations of staff and so on. In particular, a series of questions were asked about the background of the department involved, their involvement in the technology, specific targets and problems, strengths and weaknesses and the particular departmental responsibilities and background of the individual concerned. Interviews undertaken with the bench researchers had a project-focus with more detail collected about the background of a particular (current or previous) university-industry interaction in which the researchers were involved. This encouraged the respondents to talk through a particular project and reflect upon 'how typical' these experiences were.

The second section of the interview schedule investigated the linkage activity of the organisation or project. In particular, the general linkage activity of the researchers and their own methods for creating linkages, individual and departmental strategies and uses and sources of external knowledge. Discussions around these points were particularly useful for understanding individual researchers expectations and typical experiences of research linkage and sponsorship.

The third part of the interview initially focused primarily upon the knowledge transferred between university and industry through use of the composite typology of innovation knowledge (Faulkner, 1995). However, as discussed above in 3.2, this was removed from the interview schedule with later respondents and the discussion was exclusively centred on the other related areas of the third section. These focused upon the linkages that the researchers were currently undertaking. In particular, the extent to which their work was tailored to industry, the pressures from, and influence of, industry on their work in terms of research aims and ideas for research and the steps that they take to transfer the outputs of their research to their sponsors.

The final part of the schedule covered the attitude of the respondents towards linkages, their expectations and impressions of linkage, and allowed for clarification of the data collected in the third section through the further discussion of their experiences of linkage. In particular, their attitudes towards the importance of technology transfer from university to industry and how important this was in terms of their own research work was discussed. University respondents were also asked their opinions about their place in relation to industry – for example, did they feel as if they were part of the oil industry community, or were they merely academics undertaking research that happens to be of interest to companies in this sector? These more personal issues were addressed at the latter stages of the interview as it was hoped that respondents would be more relaxed and comfortable with the interviewer and therefore give more considered answers.

Interviews typically lasted between and one and two hours, with those conducted towards the latter stages of the interview process at the shorter end of the range. This occurred for a number of reasons. First, the removal of the typology of knowledge

significantly reduced the amount of time required for the third section of the interview and thus the overall interview time. Second, as I became more familiar with the area I was investigating, the interviews became more efficient and smooth running as less time was needed to discuss related topics.

All interviews bar one were tape recorded (this exception was as a result of the respondent not wishing to be recorded and in this case notes were taken throughout and after the interview). Interview tape recordings were transcribed in full and analysis undertaken with NUDIST qualitative analysis software (see section 3.8.3 below).

3.6 Data Collection: The Survey Questionnaire

The second stream of the data collection process consisted of a postal survey of university researchers active in industry research linkages in the oil and gas sector.

One of the aims of the survey was to assess the level of involvement of university researchers in industry related research. Accordingly, the respondents were purposively sampled (Robson, 1993; p.142) to target all researchers employed at a UK university who were previously or currently working some form of research project partially or wholly funded by an oil and gas related company.

3.6.1 Selecting Survey Participants

The exact scale of the survey was difficult to assess initially as the numbers involved were dependent upon the number of candidates that could be found in university departments. Early interviews had suggested that although there is an extensive amount of oil and gas research being undertaken by university researchers in the UK, the majority of this was being undertaken at a small number of institutions.

Respondents from a small number of institutions would have provided a small and limited range of data. To ensure that the survey was as extensive as possible, the sampling process was designed to access as a wide a variety of university-industry interactions as possible. The university departments appeared to fall into five main types in terms of their relations with the oil industry. These could be described as

general earth science, oil focused earth science, oil research centre (commercially focused), general engineering, oil focused engineering. These five types of university department were located in different types of university - traditional 'ancient', 'red-brick' and 'new' (post-1992) universities.

To ensure that all of these universities were accessed, the first stage of the selection process consisted of a web-site search. A complete list of the universities in the UK was obtained from the HEFCE and SHEFC web-sites and this was added to knowledge of relevant research institutions from the previous interview research undertaken. Each university web-site was then accessed in turn, with the relevant departmental types listed above searched for and examined to assess any potential or current oil and gas related areas of interest or research.

If any relevant work was found, a key researcher or departmental head was noted and then contacted by telephone to confirm, firstly, that relevant research was indeed being undertaken in the department and, secondly, to ask if they would be willing to complete the survey. It was hoped that by introducing the research through a telephone conversation, rather than in writing, potential respondents would more readily take notice of and appreciate the value of the research and be more likely participate in and respond when they received the survey. Thirdly, these contacts were asked for any other researchers in their department, or at the university, that were conducting relevant research and would be willing to participate in the survey. This 'snowball' method was utilised to gain the most effective and suitable sample for meeting the aims of the survey. It was hoped that in seeking the recommendation of a member of their department or university, that the willingness of these additional respondents to respond would be enhanced.

All potential respondents were assured of confidentiality and anonymity for both themselves and their institutions in the results, with each survey being anonymously numbered. The respondents also had the option of requesting a copy of the summary results of the survey. Bryman (1987) suggests that "researchers often offer research findings [to survey respondents] to infuse an element of reciprocity in the research" and that this is likely to enhance response and full engagement by the respondents. In

this case it was hoped that the results of the survey might be of particular interest to respondents, who spend a considerable amount of time attempting to access industrial funding.

By the methods outlined above a final list of 87 respondents to be sent a survey questionnaire was obtained. This covered a total of 19 departments from 15 universities. Four weeks after sending out the surveys, each respondent who had not returned their questionnaire was contacted by email to be reminded of the survey. This resulted in an increase in the response rate, from 35% to a final value of 46%, which was a satisfactory response rate given the length, and at times potentially sensitive nature of the questionnaire and the fact that due to the desires of the sponsors of the survey it had to be distributed in early summer when academics are busy with examinations or may already be on holiday.

3.6.2 Questionnaire Design

Insights from the early interviews enabled the survey to be tailored to address key issues (see Appendix A for a copy of the questionnaire). Although the three key objectives of questioning (in line with the research questions of the types and extents of linkage, the benefits of linkage and the relationship between university and industry) suggested a format designed around these foci, the questionnaire was designed around three different sections. This aimed to cover all of areas of questioning to be included in the survey, but enabled the questions of the respondents to be asked in a progressive, coherent and easy to answer manner. It was hoped this would encourage a high response rate, as respondents would find it easy to complete, see the relevance and value of the research and remain interested enough in the survey to continue until the end. The survey was piloted by a small number of academics to refine the design and layout.

The three sections focused on the topics of: building linkages with industry, types and extent of linkages and reflections on linkages. These three sections utilised a range of questioning types to investigate the various areas of interest. Although the respondents had the opportunity to elaborate on certain yes/no questions, to provide

more in-depth qualitative responses, the questions were in the main left closed to make analysis easier and to encourage full completion by respondents. Likert scale questions were also used throughout to facilitate the assessment of, for example, opinions and levels of importance of a range of criteria. This was done not only to remove the need for large amounts of coding that open questions demand, but also to encourage more considered answers as the respondents could compare different answers and explore their ideas more extensively. In addition, Likert scale questions are a familiar format and it has been suggested that they look “interesting to respondents, and people tend to enjoy completing scales of this kind” (Robson, 1993: p.181) and these types of question are likely to be appealing to respondents with a mathematical or scientific background. The problem of restricting responses through limiting the number of options when utilising this form of question to assess particular topics was addressed by offering respondents the opportunity to add an additional criterion.

The first section covered basic information surrounding the researcher and their involvement in industrially related research. This included methods of making new contacts, barriers to gaining funding and levels of tailoring of research. It was hoped that these questions would be easy for the respondents to answer and would introduce and interest them enough to continue with the remaining, more complicated questions within the questionnaire. The nature of the purposive selection process meant that there was no need to ask respondents their individual characteristics related to this survey (all the relevant information was already known - e.g. type of university department, position etc.). This had the added advantage of reducing the number of basic, and perhaps therefore uninteresting, questions for the respondents at the beginning of the questionnaire.

The second section was the largest of the three sections and contained questions investigating details about the mechanisms of linkage being undertaken by university researchers. This was the most demanding section in terms of the information required of the respondents and as such was designed to be as easy as possible to complete. It aimed to obtain information on an extensive range of mechanisms of

linkage from short-term consultancy work, through PhD sponsorship, to fully funded research projects. Although there was a certain amount of commonality between the information being asked about the different mechanisms of linkage, it was felt that the individual features of each type were sufficiently different to require a separate sub-section. This was necessary to prevent any ambiguity in questioning that may have been caused by generalised requests for information covering the whole range of linkages.

Certain questions, particularly in relation to information about sponsoring organisations and levels of funding, could be sensitive to respondents so care was taken in wording questions carefully. Respondents were given the option to name the type of sponsoring company (e.g. 'oil operator') rather than specifically naming the company. Although this would provide less precise data, it would enable the level of funding of different types of companies to be assessed without forcing respondents to divulge information that they were uncomfortable to disclose. It was also hoped that showing this sensitivity about issues of confidentiality would again encourage researchers to engage fully with these and later questions.

The third and final section of the questionnaire asked the respondents to reflect upon their experience of linkages. In particular, their impressions of their working relationships with members of industry, the importance of external research funding to the university and their perspectives on the quality of sponsored research. In addition, respondents were also asked to assess their knowledge contribution to the linkages utilising a condensed version of Faulkner's (1995) composite typology of innovation knowledge. This was included in the questionnaire because at the time of its design this had not been removed from the interviews and it was hoped that this condensed tool might have provided further insights into the types of knowledge that the universities provided for industry.

3.7 Data Analysis: Introduction

The sections that follow will describe the process undertaken to analyse the data collected through both the interview and the survey research and how these findings

were developed into theory. Although the interview and survey analysis was undertaken concurrently, for clarity these will be outlined separately. The final development of the findings into theory was undertaken utilising both sources of data and this shall be described separately below. Although the interview questionnaires developed alongside the research process, with slight changes in areas of questioning, the interviews were analysed collectively as the same themes were covered throughout the full range of interviews. Indeed, due to the nature of semi-structured interviewing and in particular as I was exploring the experiences, attitudes and perceptions of respondents, in many cases the interview schedule became more of a reminder of points to be covered rather than a strict interview guide. Interviews were undertaken as conversations on linkage activity and as a result all interviews could be analysed collectively.

3.8 Analysis of Interview Data

The analysis of the interview data occurred through a number of phases. These comprised reflections and analysis undertaken immediately post interview, during transcription, throughout the formal coding process, during analysis of outputs/reports of codes and throughout the writing up of the findings. As is suggested by the length of time these ‘phases’ cover, the analysis of the research material collected was not an ‘end-of-pipe’ process, it occurred throughout the course of the research. This is in common with much qualitative research and Bryman (2001: p.389) describes this approach as “iterative – that is, there is a repetitive interplay between the collection and analysis of data. This means that analysis starts after some of the data have been collected and the implications of that analysis then shape the next steps in the data collection process”. An obvious example of this ‘iterative shaping’ of the research is in the discarding of certain parts of the research (use of the Composite Typology of Innovation Knowledge) and focusing in greater detail upon other aspects. Without undertaking analysis and reflection throughout the data collection process these decisions could not have been made. This continuous analysis was also aided by reading new literature and re-reading older literature that echoed findings and themes as they arose from the data.

The analysis was consistent in that it was, from start to finish, framed around the three main themes, namely the types and extent of linkage, the benefits of linkage and the relationship between university and industry. However, throughout the analysis aspects within these themes became more or less important or focused upon. These five phases of analysis, and the key decisions taken during these phases, shall be described in turn below. In particular the use, implications and influence on the analysis of the qualitative analysis software package NUD*IST 6 shall be discussed.

3.8.1 Post Interview Analysis

The initial stages of analysis of the data were undertaken immediately after the interviews. This consisted of reflection upon the topics covered during the course of the interview and any particular themes that had arisen. This was the preliminary stage of analysis and was undertaken through note taking and reflection after the interview had occurred. This was often undertaken on a train journey home after interviewing and was extremely useful in reflecting on key responses by respondents and areas that may be probed further in future interviews. In addition, information regarding the 'tone' or progress of the interview (e.g. whether the respondent appeared open or guarded, or if there were many interruptions that stopped the flow of the interview) was noted to add information and aid later, more formal analysis.

During and after the later interviews, I was able to reflect on how both the respondent compared to others I had interviewed and also on how the information that they reported related to the experiences of others. This in particular assisted in the early stages of the theory building process.

3.8.2 During Transcription

The first major steps in analysis were taken during the interview transcription process. Interviews were transcribed by myself as soon as possible after the interviews had taken place. Although this process was time consuming (as a result of my slow typing speed), the time spent considering each interview was invaluable in the analysis process. As the interviews were played back and transcribed, I had the

opportunity to consider the responses of the respondents and took a large number of memos highlighting particular behaviours or attitudes, linking and cross referencing these to other interviews, recalling particular aspects of the literature that I had read and noting suggestions for theories and methods of formal analysis.

By the end of each transcription I typically had two pages of such notes and these greatly assisted in the preparations for the more formal coding process. As described above, the formal coding process was arranged around three main themes of the PhD to make both the analysis and report writing processes more manageable, namely the types and extent of linkage, the benefits of linkages and the relationship between university and industry. The final decision to remain with these three themes was made as the formal coding process began and was influenced by the data gained from the survey research results.

3.8.3 The Coding Process and Use of Qualitative Analysis Software

When all the interviews had been transcribed, a formal coding process was undertaken. This course was chosen as I did not wish the coding process, in particular the choice of codes, to be overly influenced by findings from the earlier interviews. I felt that after undertaking and transcribing all the interviews, and gaining insights from the survey research, the coding process would be more effective as I would be more intimate with the key themes and findings.

I chose to utilise the NUD*IST 6 qualitative analysis software package to facilitate the coding and analysis process for two main reasons. The primary reason was that I felt qualitative analysis software would be offer advantages over the traditional manual 'cut-and-paste' method of coding. I had chosen to utilise a straightforward 'code and retrieve' methodology based around aspects of the three key themes of my research. This approach fitted in well with the capabilities of the NUD*IST package. I hoped that the codes that had been suggested by my preliminary analysis, when 'retrieved' from the software package in the form of reports, would enable me to analyse the relevant topics efficiently. In addition, I chose to use this particular

package as it had been recommended and was easily available to me at no cost through my department.

There has been much debate about the use and implications of qualitative analysis software in recent years (see for example, Fielding and Lee, 1991; Richards and Richards, 1994; Kelle 1997; Buston, 1997). Much of the debate has covered the concerns over a loss of control of coding and analysis by the researcher to the procedures dictated by the computer software. Bryman (2001) summarises these three key concerns as follows. First, that the ease with which the data within the packages can be quantified may lead to a temptation to quantify findings and lose the in-depth contextual descriptions that forms the strength of qualitative data analysis. Second, the nature of the software may reinforce or exaggerate the 'code and retrieve' nature of qualitative analysis and subsequently lead to the loss of the narrative flow of the interview transcripts. Similarly the software does not facilitate other styles of analysis. Third, the ease with which the data can be grouped and regrouped into related 'chunks' of text risks the decontextualising of the data. Placing findings in context is a key strength of the qualitative process and losing this is a key concern for researchers.

These concerns are tempered by a general acceptance that the software does indeed offer great assistance to the qualitative researcher in storing and managing large amounts of textual data, both saving time for the researcher and also enabling flexibility in the analysis process. Buston (1997: 3.2) suggests, "one of [NUD*ISTs] advantages over manual methods is the relative ease with which the researcher can switch between different phases of data analysis". Bryman (2001) also points out that the software can assist the researcher in relating findings to socio-demographic and personal information such as age, profession etc, and can help in making the whole analysis process more transparent, as researchers are forced to be more explicit and reflexive about the process of analysis. Although quantification of data was suggested as a potential problem in using qualitative analysis software, Silverman (1985) suggests that some quantification can be useful in qualitative research and the

use of the software in analysis to broadly assess the frequency of findings can assist the researcher in the reduction of anecdotalism in analysis.

My experiences of utilising the software broadly mirrored the advantages and concerns described above. I found coding through the software incredibly useful and time saving. In particular, the flexibility of the software enabled me to easily return to documents for re-coding in light of new insights occurring during the process and to easily code certain text units under a number of different headings when required. Fortunately concerns over the loss of context through breaking the data reports containing many 'chunks' of data from different respondents did not affect my research. As I had a relatively small number of respondents and had undertaken the interviews, transcription and the preliminary analysis described above, I had an intimate knowledge of the data, respondents and a sense of the relationship that had developed between interviewer and respondent. This resulted in a situation in which I rarely encountered a 'chunk' of data that I could not relate directly to its interview and could therefore place in context. This enabled me to maintain the context throughout the analysis process. It is unlikely that this would have been the case if I had a larger number of interviews or had not been wholly responsible for interviewing and transcription alongside analysis.

I did find, however, that the software lead me to 'over-code' at times. The tree coding structure (outlined in detail below) was useful in organising the coding process, but the ability to very easily code and 'sub-code' along the many sub branches of the 'tree' meant that I had to revise my initial strategy. The coding became too specific and the subsequent reports almost too small to be useful. This perhaps echoes the concerns over loss of context indicated above. Once I had realised this limitation I took a step back and only utilised longer coding reports from the 'thicker' branches in my analysis, as I felt that to persist to far with the tree coding would have been too restrictive. This left me with a sense that perhaps I had not utilised the software fully. Indeed, by the end of the process, I felt that the software had merely acted as a tool in manipulating the movement of text chunks and not specifically in the analysis process. However, the acknowledgement that "the

process of coding the data is the preliminary for the actual analysis in which the analyst tries to make sense of the data” (Kelle, 1997: p.15) suggests that my decision to finish utilising the software at that point was not detrimental to my analysis.

I utilised the coding tree structure within NUD*IST throughout the coding process. This began with the three main themes (types and extent of linkages, benefits of linkages, and relationship between university and industry) as three main branches. From my preliminary analysis I already had a list of suggested ‘sub-branches’ or ‘sub-codes’ coming off these main themes, but was flexible and open to changes in the coding structure. Indeed, when re-reading and formally coding the interviews more of these arose, leaving me with a larger tree than perhaps I would have expected. These new codes subsequently yielded new and interconnecting insights and the tree structure was useful for developing these.

In addition to these coding trees I also utilised the ‘free nodes’ option to code for background information gained from the interviews. These covered, for example, ‘industry details’ – a collection of comments on industry developments and situations that were not directly relevant to the themes that I was investigating, but that I thought may help to contextualise some findings. When read together as a large coding report, these also helped to clarify my understanding of the sector as a whole and were surprisingly useful in this aspect.

The final outputs of the software ‘analysis’ process were a collection of coding reports, ranging from two to approximately ten pages, from which the true formal analysis was undertaken. This process is described in the next section.

3.8.4 Analysis of Coding Reports

As indicated above, not all of the nodes were printed out and analysed individually, the majority of the coding reports were from the ‘thicker branches’ of the tree (i.e. including sub-branches in one report). This meant that when reading through and analysing the text, a more broadly grouped selection of text was presented. This not only enabled me to easily compare and contrast the responses on particular topics,

but also to provide more context on respondents' attitudes and perspectives (e.g. through looking at the perceived barriers to funding *and* individual strategies to overcome these at the same time).

Again, memos that I had both noted during the transcription and the coding process influenced and guided the analysis of the reports of the interview data. Key themes were investigated around the main codes. The research questions focused upon gaining insights into the attitudes and behaviours of those involved in the university-industry research process. As a result the analysis sought to bring together findings on the three key areas – types of linkage, benefits of linkage, and the relationship between university and industry. These topics were broken down to varying levels by the coding reports and themes and patterns of responses and investigated.

The analysis during this stage was assisted by the data from the survey on a number of occasions. The large number of responses from the survey gave me greater confidence in assessing how 'typical' certain experiences, behaviours and attitudes were across the university respondents.

3.8.5. Writing up of Findings

During the process of presenting the findings in formal written form, further analysis and reflection was stimulated. The process of writing up findings in depth, and comparing these with the literature meant that I spent further time analysing the implications of the findings. It also enabled the ideas that are presented in Chapter 7 of this thesis (the collaborative outlook) to be developed.

3.9 Analysis of Survey Data

The analysis of the survey data was conducted using Microsoft Excel spreadsheet software. As the aim of the survey was to conduct a descriptive survey no advanced statistical analysis was used. Subsequently, Excel provided an effective (and to me familiar) tool to undertake a simple descriptive statistical analysis of the data produced.

The software was particularly useful in creating graphical representations in the form of bar charts and histograms to assist in apprehending the data. Predominantly, the analysis consisted of frequency tables (showing, for example: number of research projects held by researchers, number of sponsors for these projects, levels of funding etc), some of which were presented graphically. In addition, the Likert scale questions were also represented by bar charts (e.g. perceived importance to industry of projects).

A further level of analysis was attempted by calculating a 'linkage score', for each respondent from particular responses. This attempted to examine the results by separating researchers by factors that may have demonstrated a high or low propensity to linkage. This process is explained in more depth in Chapter 4. It was not built in to the design of the survey but was pursued because, through the interview research and analysis, the characteristics of the researcher emerged as an important feature in understanding differing levels of research linkage.

The survey also contained a smaller number of open questions relating to, for example, the researchers' perceptions of barriers to gaining funding. The responses to these types of questions were coded (without the use of software) and the frequency of different types of responses noted. In line with Silverman (1985), this type of analysis helped to suggest the generality of the findings in both the survey and the interview data.

Although conducted in parallel, the survey was analysed separately from the interview data and, as a result, is presented before the other findings in a separate chapter. This allows the survey to 'set the scene' for the in depth investigations of individual experiences of linkages from interviews presented in the subsequent chapters.

The use of certain areas of questioning facilitated direct comparison with a major recent cross sector survey of university-industry linkages (Howells et al, 1998). This is reflected upon, along with other key findings, in the conclusions to Chapter 4.

3.10 Final Analysis and Theory Building

The structured analysis of the interview and survey data around the three themes of types, benefits, and relationships in university-industry linkages provided a useful frame to gain an understanding of the main features and themes that are involved in these processes in this particular sector. In addition, this enabled these themes to be easily compared and contrasted with the relevant information gained from the literature, as described in Chapter 2.

As has been mentioned above, the importance of understanding the university-industry relationship and university researchers' attitudes towards industry developed and became increasingly central to my understanding of university-industry linkages as the research progressed. The discussion of relevant literature in Chapter 2 highlights the theme of differences between the behaviour of university researchers involved in linkage and stresses the necessity of understanding the university-industry interaction process as a non-linear two-way interaction.

This growing awareness led my investigation of the data to become focused on explaining the differences in researchers' behaviour and attitudes towards industry linkages and to view the university-industry linkages as an interpersonal and inter-organisational relationships. Through this I developed a framework (the Collaborative Outlook) to both classify and explain researchers behaviour through a range of characteristics and behaviour that had been highlighted by my findings. This framework was influenced in particular by Webster (1994) and Bozeman et al (2001). This is described and discussed in Chapter 7

3.11 Reflections upon the Research Process

The research process described above was effective in meeting the aims of the thesis. The development of the research methods used (as described in 3.2) developed along with the research focus and enabled the research to explore the motivations and perspectives of researchers interviewed in this thesis. The use of the survey of university researchers and interviews from the perspectives of both university and industry researchers has enabled an in-depth understanding of the characteristics of

linkage in the oil and gas sector to be gained. The comparison between these findings and literature on linkages in other sectors has allowed common themes and key sectoral differences to be identified, enabling this research to be used to inform the understanding of research linkages in general.

However, having undertaken the analysis and in particular explored the importance that the attitudes, experiences and behaviour of researchers have on the generation and practice of linkages there are some small changes that could be made to provide a deeper understanding.

A key change to the research process would have been to collect further data on the industry figures involved in linkage – in particular this would have enabled the ‘Collaborative Outlook’ of industry contacts to be explored (although, as has been indicated in the 3.2, the data on this group of respondents was limited due to their low involvement in research, and the difficulties in locating respondents for interview) and compared and contrasted with university researchers that they were linking with.

Investigating the factors that make up the ‘Collaborative Outlook’ of university researchers could have been further undertaken through a longitudinal study of a number of university researchers in particular departments. This would enable the effect of the institution on researchers’ behaviour and attitudes to be tracked over time, as the institutional effect on researchers’ ‘Collaborative Outlook’ further examined. A number of departments with different levels of linkage and expertise could be chosen for the purposes of comparison. However, as the importance of this was not apparent to me until well into the data collection stage, time limits prevented such a study being undertaken.

3.12 Conclusion

This chapter has presented the methods through which this investigation of university-industry research linkages in the oil and gas sector has been undertaken. A mixed methods approach was used. A survey of university researchers active in

linkage was undertaken and used to gain information on the mechanisms and extent of linkage in the sector, the barriers to linkage and an overview of university researchers' perceptions and behaviour in linkage. This was allied to a number of qualitative interviews of university and industry figures involved in linkage to gain in depth information on the attitudes to and experiences of those involved in linkage and to facilitate an analysis of the factors that explain the behaviour of individual researchers involved in linkage.

This research design captured the strengths of both mechanisms of research, and facilitated in the exploration of the research aims of this thesis – to explore the range and extent of linkage, the benefits and barriers of linkage and the role of individual researchers in the linkage process.

The findings from the research are presented over the next three chapters. First, in Chapter 4, findings from the survey are presented and discussed. Chapters 5 and 6 present the in depth data from the qualitative interviews. These are followed by Chapter 7, which develops the 'Collaborative Outlook' framework, and final analysis and conclusions are presented in Chapter 8.

4. A Survey of University Researchers Involved in Oil and Gas Industry Linkage

4.1 Introduction

This chapter presents the findings from the postal questionnaire survey (see Appendix A) of 40 university researchers¹ involved in oil and gas related university-industry linkages. The results from the survey are compared with findings from the literature reviewing linkage activity in all sectors in the UK (see 2.3). This creates a context to examine specific aspects of research linkages in further depth in subsequent chapters.

The key aim of the survey was to assess the level of involvement of university researchers in linkage with the oil and gas industry and to examine their attitudes to these linkages. The survey sought to elicit information from the sample of researchers in three broad areas. These were the extent to which the researchers linked with industry, the benefits they experienced from these linkages and the nature of their relationships with industry including any barriers to linkage. Acquiring a fully accurate and exhaustive audit of the relevant research in the UK was beyond the scope of the study. Rather, the survey was designed to give a good indication of the range and typical levels of funding going into universities from industry and the nature of the work being so funded.

Researchers such as Rahm (1994), and Santoro and Chakrabarti (2002) classified university researchers by their differences in attitudes and behaviour to linkage. To explore if these differences could be identified in this study, the linkage activity of the researchers was scored by responses to certain questions to assess if any clear distinctions in linkage behaviour could be identified in this sample. This process is described in the first section. The results obtained from the survey are then described

¹ This survey was conducted with funds from a major oil company, whose commissioned the work to investigate university researchers (for full details see chapter 3)

below, in line with the research key research areas of this study – extent and types of linkage, benefits of linkage and barriers to linkage.

4.1.1 Analysing researchers by linkage activity

The respondents in this survey were targeted to ensure that all were undertaking some form of linkage with industry. However, the research literature suggested (e.g. Rahm, 1994; Butler and Birley, 1998; Klofsten and Jones-Evans, 2000) that within this group there would be diversity in attitudes towards linkage. Rahm (1994) and Santoro and Chakrobarti (2002) identified high and low linking researchers in their studies and to explore this in this study, a linkage scoring system was developed to categorise respondents in terms of their linkage activity. The decision to categorise the linkage activity of the respondents in this way was made after initial analysis of the data and was not built into the survey.

Four key variables were identified from review of the literature and initial analysis of the survey as being related to level of involvement in university-industry linkage. These were the number of industrially sponsored research projects currently in progress, the level of informal contact made with research sponsors, their involvement in consultancy activity and their involvement in industrially sponsored PhD. supervision. For each variable the researchers were given a score of one or zero (with one indicating high linkage activity and zero indicating low linkage activity) and then their total score was summed to give the ‘linkage score’ for each individual. The scoring system is summarised in figure 4.1 below.

Fig. 4.1 Calculating linkage activity score

	Linkage Score	
	0	1
No. of research projects	2 and under	3 and over
No. of instances of informal contact with sponsors / year	11 and under	12 and over
Undertake consultancy?	No	Yes
Supervise sponsored PhDs?	No	Yes

The criteria for each different linkage score were created so as to split all the responses of each question, as far as possible, into two. Therefore, for the criteria which were presented as frequencies, the median number or more (3 for research

projects and 12 for instances of informal contact) were given a score of one. The criteria with an approximate 50-50 split of responses to yes / no questions (did the researchers undertake consultancy work or supervise PhDs) were scored either one or zero. It is important to note that because the scores were developed from analysis of the data, they were ‘grounded’ in the data.

This resulted in the respondents falling into five groups, as outlined in figure 4.2 below. The distribution of the respondents across groups meant that the researchers could not be split simply into two separate groups of ‘high and low’ linkers. This suggests a broad range of linkage behaviour within the group, with no clear dividing line between researchers. This contrasts with Rahm’s (1994) finding that there were clear distinctions between ‘spanning’ or ‘university bound’ researchers.

Fig. 4.2 Overall linkage scores (n=40)

Overall Linkage Score	Number of respondents
0	3
1	6
2	9
3	10
4	12

The data for all respondents were analysed and aggregated both overall and by linkage score. The results sections that follow present the aggregated data for most questions. This approach was taken because, in general, there was little difference between the responses by the researchers with different linkage scores. However, in a small number of cases, significant differences did arise and these shall be described where appropriate.

4.2 Extent of Linkage

The survey provided data on the range and extent of different types of linkage conducted by university researchers. These are summarised in the figure 4.3.

Figure 4.3 Respondents linkage activity by linkage type (n=40)

	Sponsored Research Projects	Sponsored PhDs Supervised	Consultancy	Industry Funded Posts
Researchers undertaking	97.5% (39)	70% (28)	80% (32)	7.5% (3)
Max no. per researcher	20	12		
Min no. per researcher	1	1		
Med. No. per researcher	4	3		

A very high percentage of respondents (97.5%) were involved in industrially sponsored research projects. This is unsurprising due to the purposive sampling of the survey (that is, specifically targeting researchers that are active in industrially funded oil and gas related research). A high number of supervised industry funded PhDs is also noted (70%) along with 80% of researchers being involved in some sort of consultancy work. Only a small number of researchers had their posts directly funded by industry (although many researchers may have required the funding that they obtain for projects to maintain their position at their university – this was not explicitly investigated in this survey). These different types of linkage are described and analysed in depth in this section.

4.2.1 Sponsored Research Projects

The data collected on research projects currently being conducted, or recently completed, provides an indication of the level of involvement of the different oil related companies in university research. Researchers were asked to give details of up to three oil sponsored research projects, although some reported that they were involved in considerably more. In total, information was collected on 85 individual projects. Of these, 57% were funded by more than one oil related company, with up to 20 partners involved in some cases.

Each instance of individual company funding was recorded, resulting in 314 separate ‘instances’ of funding by oil related companies (i.e., if a single project was sponsored by ten companies, this resulted in ten ‘instances’ of funding). As respondents were given the option to provide information in two ways, to alleviate any fears of

confidentiality - identifying by name, or describing by company type, two different types of information were gathered. These comprised a list of specifically named funding partners and a list of the company type of the funding partners. This provided 166 specific instances of funding by individual companies and 148 non-specific instances of funding by company type.

The distribution of the specific instances of funding is described in figure 4.4 below, and shows that two large oil operators were involved in significantly more projects than any other companies. Of the 166 funding instances by company these two companies each provided approximately 15%. The remaining 70% of funding instances mentioned were spread between 25 other companies, with the 6 largest of these each providing 6% to 10% of the funding instances.

Fig. 4.4 Distribution of research funding instances by company. (n=166)

Company	No. Projects	Percentage
BP	23	14
Shell	22	13
Amerada Hess	13	8
Exxon-Mobil	11	7
TotalFinaElf	11	7
Statoil	10	6
Enterprise	9	5
Norsk Hydro	7	4
Others*	60	36

*Others consist of a total of 60 instances of funding from 19 different firms: Approximately 60% operators and 30% contractors

These specific instances of funding were categorised by company type and then added to the non-specific instances of funding to give an overall distribution of funding by company type (see fig 4.5 below). This shows that almost three-quarters of the funding instances came from the oil operating companies. Operating companies are all large firms and this echoes findings from the literature (e.g. Faulkner and Senker 1995b; Corsten, 1987; Shane, 2002) that indicate that likelihood of linkage increases with the size of firm.

Fig. 4.5 Distribution of funding instances by company type. (n=314)

Company Type	No. Projects	Percentage
Operators	204	65
Contractors	62	20
SMEs	17	6
Others	11	3
EPSRC	4	1
NERC	4	1
Dti	12	4

The level of contribution of these funding instances varies greatly, along with the number of sponsoring partners per project. As a result, the range of funding per sponsor goes from a minimum of £3,000 to a maximum of £250,000 per annum (although it was indicated that some smaller projects received no cash funding, with equipment or access to data taken as payment in kind).

Fig. 4.6 Levels of funding of industry sponsored research projects (yearly) (n=85)

	Funding per project (£)	Funding per sponsor per project (£)
Mean	117 000	35 000
Median	75 000	25 000
Maximum	600 000	250 000
Minimum	3 000	3 000

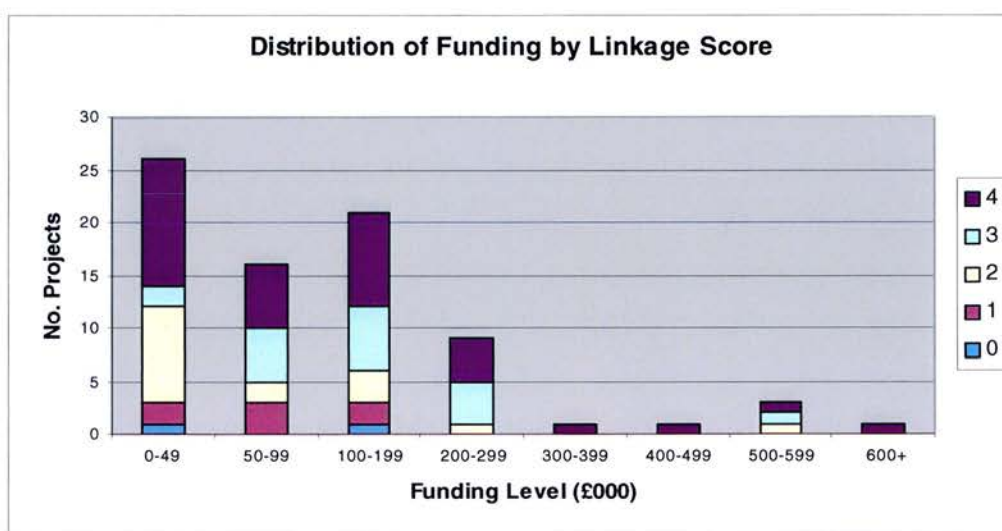
As can be seen in figure 4.6 above, the mean levels of funding differ somewhat from the median due to a small number of heavily sponsored projects. These projects were all located in institutions traditionally associated with the oil and gas industry:

Heriot-Watt, Aberdeen, Newcastle, Edinburgh, Cambridge, Imperial College. The median gives a better indication of a typical level of funding for an oil industry sponsored project, approximately £25k per year for three years with three funding partners, making £75k per year the typical level of funding for an oil industry project. Data was not available to assess this scale of funding relative to other sectors.

The majority of the research projects were within the £0-199,000 range, with only a few projects in the higher range of £300,00-600,000. If projects are divided up by the researchers linkage activity (see figure 4.7 below), it is shown that the greater number of projects were held by those with a higher linkage score. In addition to this, the graph shows that the higher funded projects were held by those researchers with the higher linkage score. This is significant as the linkage score does not incorporate the

value of projects as one of its contributing factors (see figure 4.1). This suggests that the more involvement on a formal and informal basis that the researchers have with their current and potential sponsors, the more likely it is that they will be able to generate the large levels of funding required for these large projects. The literature indicates that informal linkage is important to successful linkages (e.g. Rappert et al; 1999; Davenport et al; 1999) and this finding appears to corroborate this. In addition, although not directly comparable, this also echoes the Howells et al (1998) finding that the top 7 UK universities in terms of industrial research income receive a third of the funding, as it indicates a concentration of funding with a small number of ‘elite’ researchers.

Fig. 4.7 Project funding by linkage score



4.2.2 Consulting

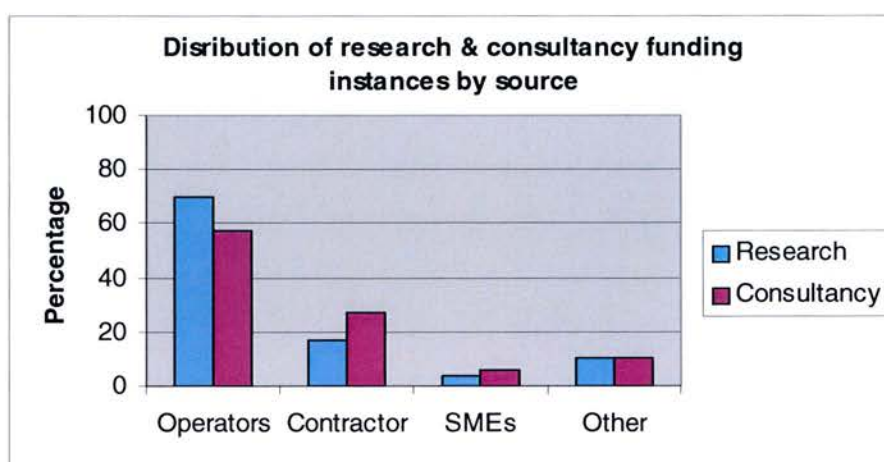
80% of respondents were involved in some form of consultancy activity, with the average (mean) duration of this being one and a half weeks. A maximum of 8 weeks per instance of consulting and a minimum of one day was reported. The consultancy work was spread across the range of companies active in the sector, as shown in figure 4.8 below.

Fig. 4.8 Distribution of all instances of university consultancy work by company type per year

Company Type	Consultancy instances/yr.	Percentage
Operators	85	57
Contractors	39.5	27
SMEs	15.5	10
Oil Consulting Companies	8.5	6

If the distribution of funding sources between the consultancy work and the research projects described above are compared, a number of differences emerge (see figure 4.9 below). Although the operating companies as a whole accounted for the majority of funding instances for both consulting and research projects, they invested a higher proportion of their funding instances on research projects.

Fig. 4.9 Percentage distribution of funding instances for consulting and research by company type



By contrast, the contractor/service companies invested a significantly larger proportion of their funding instances on consulting projects. Consulting through the SME sector was also more prominent relative to sponsored research. This increase in the proportion of consulting funding coming from the contractor and SME groups is likely to be due to these types of firms requiring more shorter term knowledge and technologies, as opposed to longer term speculative research, and is in line with their working practices which have been found to be more contract based (Corsten, 1987; Shane, 2002). In addition, as noted in 2.4.3, the smaller firms are also unlikely to have the budgets available for the long term research undertaken by university researchers (Mowery, 1998).

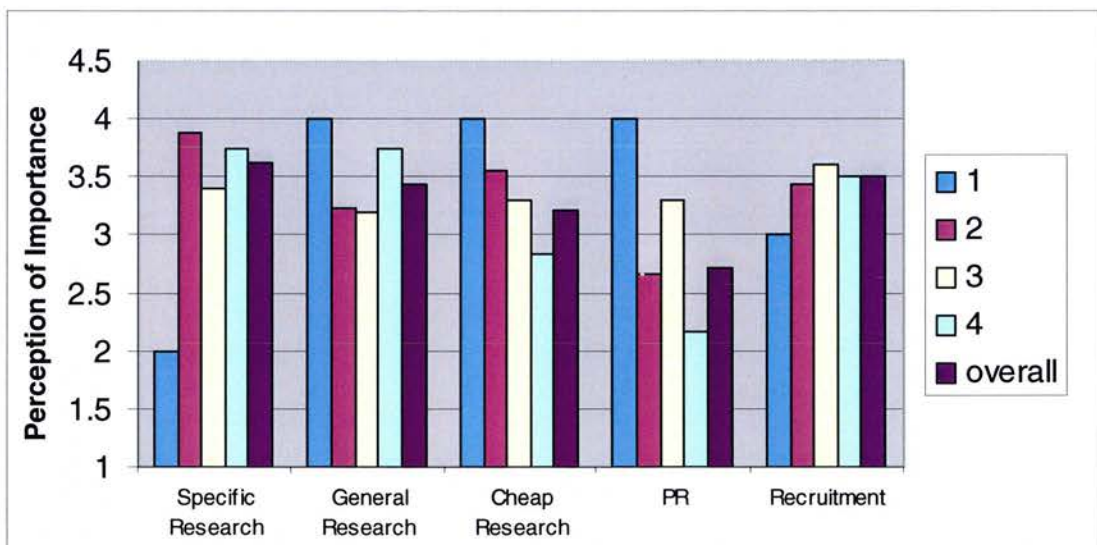
4.2.3 Industry Sponsored PhDs

70% of respondents were supervising industry sponsored PhD projects, each typically supervising 3 students. University researchers were in contact with PhD funding partners on a regular basis, with formal meetings approximately twice a year.

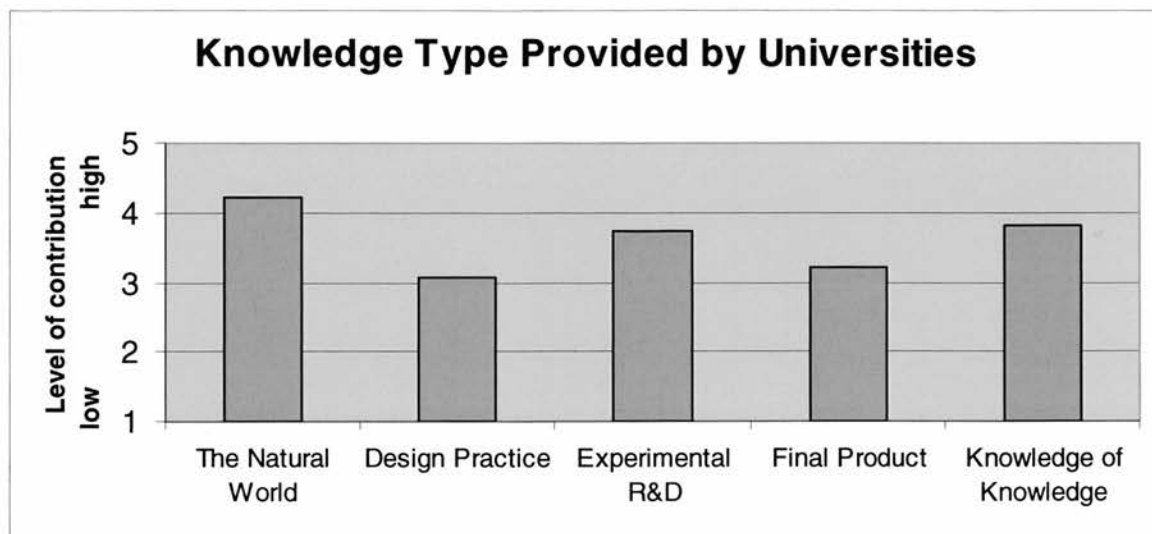
Informal contact through telephone or email correspondence typically occurred one or two times per month and in some cases as much as three times per week.

Respondents reported that this regular informal contact between the company and the university researcher was an important part of the PhD studentship relationship, as the academics indicated that the greatest benefits to the sponsoring companies were access to research and recruitment. As discussed in 2.3.1, the literature also found that this regular contact and interaction with both the supervisor and the PhD student was important as a preliminary to recruitment and selection of the student by the company and also important to researchers as a possible step to larger linkages in the future (Bloeden and Stokes 1994; Salter et. al, 2000).

Fig. 4.10. University researchers' perceptions, by linkage score of benefits to companies, ranked high (5) to low (1) in sponsoring PhDs.



The range of perceived benefits to the sponsoring companies of funding PhDs were given broadly similar weighting by the researchers in the survey. However, when these were examined in relation to the linkage score of the researcher, a notable difference was found in the perceptions of the researchers of two of the potential



4.4 The University-Industry Research Relationship

This section of the results deals with the relationship between the researchers and their funders in industry, specifically focussing on, first, the barriers that university researchers perceive to exist in obtaining research funding, and second, the working relationship between academia and industry during linkage.

4.4.1 Barriers to Obtaining Funding

Over 70% of the university researchers surveyed reported that there are barriers to gaining the funding they desire from the industry. Respondents were given the opportunity to explain the nature of these barriers in an open ended question. Most respondents indicated only one barrier, although some suggested more, resulting in 28 respondents providing 33 responses. These qualitative responses were coded into the nine different barrier types and the percentage of respondents citing each barrier calculated. These are shown in shown in figure 4.12 below.

The respondents were aware of the economic constraints of their sponsors, with 30% citing the influence that fluctuating oil prices have on the R&D budgets of oil companies as a problem in terms of accessing the funding they desire. However a number of other barriers were noted by researchers, which can be grouped into two main types. First, the difference in the perspectives of university and industry, relating to the cultural differences between university and industry (as discussed in

2.3.4 and 2.6.1) and second, the importance of gaining access to the ‘network’ of researchers interested in funding (a key factor in linkage highlighted in the literature and discussed in 2.4.1).

Fig 4.12 Barriers to obtaining research funding. (n=33)

Rank	Barrier	Example response	N (%)
1	Current oil and gas industry economic climate	“Current financial climate, fear and concern for failure, technology viewed as high and expensive risk”	10 (30.3)
2	Difficulties in making contacts with relevant organisations / personnel	“You can nearly always raise oil industry funding for a good idea. The main barrier is finding people who have the time to assess it and sell it within the company”	7 (21.2)
3	Timescales and goals	“Companies often look for short term results, whereas research is often long term”	5 (15.1)
4	Lack of confidence in universities	“A sense that universities cannot produce in the required timescale”	3 (9.1)
=5	Industry doesn't understand university research process	“Industry doesn't understand the requirements of university researchers”	2 (6.1)
=5	Problems transferring knowledge	“Difficulty of effective technology transfer”	2 (6.1)
=5	Lower industry priority of blue sky research than previously	“Oil Industry much more focused on their needs than in earlier years”	2 (6.1)
=8	Universities in competition with oil service companies	“Competing with large service companies' money”	1 (3.0)
=8	Ambivalent attitude to industry funding	“Ambivalent attitude of academia to industry money”	1 (3.0)

The difference in perspectives (or cultures) of the industry and university researchers was highlighted by the responses of the university researchers to this question of barriers to sponsorship. Industry problems with the timescales and outcomes of university research were key examples of this. One respondent reported that industry “is very conservative and unwilling to get involved in speculative work where there is no short term benefit”. Furthermore, it was commonly stated (15% of the responses) that industry requires more and more focused research deliverables. In addition to this, there is a perception from a smaller number of respondents that the industry does not understand the university research process and the requirements of the university researchers (highlighting cultural differences). This was allied to other concerns that industry perceived universities as environments where deadlines could not to be met and that there was a lack of confidence in the deliverables of academia.

These responses echo many of the key barriers highlighted by the literature review relating to cultural differences between the two research contexts, such as different systems of values, the university's lack of regard for deadlines, different timescales and confidentiality issues (Corsten 1987; Howells et al, 1998; Jones-Evans et al, 1999). Respondents also suggested small levels of misunderstanding or ignorance of these differences by industry sponsors, highlighted by the 15% of responses that state a lack of confidence in and misunderstanding of the university research process.

Gaining access to an informal research network to facilitate in the generation of linkages was highlighted in the literature by many researchers (e.g. Faulkner and Senker 1995a; Davenport et al; 1999; Dickson, 1996). This is exhibited in those responses from the survey stating difficulties in finding the right person to talk to with regard to a particular research proposal. Respondents suggest that it is often the case that known contacts in industry are used and reused and, as a result of this, those university researchers with a large contact base find it easier to attract links and funding. This agrees with Harmon et al (1997: p.424) who indicated that "in the majority of cases some form of relationship existed prior [to linkage] ... from long-term friends to contacts at conferences". Respondents new to the sector, or in departments without a strong reputation in the sector, reported that they have major problems both finding the correct person within companies to create research linkages with and also to convince the companies to fund the research.

Two interesting findings occur if barriers are compared by linkage score. First, the difficulties of finding contacts within sponsoring companies is only mentioned by the researchers with the top two linkage scores, potentially as a result of their greater understanding of the importance of finding the right contacts. Yet these are those are likely to have relatively better contacts (since one of the factors for calculating linkage score is level of informal contact with industry). Second, the problems of the different goals and timescales of industry were almost all stressed by researchers with low linkage scores. The researchers with more interaction with industry appear to have fewer problems aligning their research with industrial goals, perhaps due to their increased understanding of what the industry wants out of university research.

They report that the problems are more organisational, rather than technical – which seems to concur with Senker’s (1990) suggestion that ‘finding out what each other wants’ and friendship are key factors in success of linkage

When the overall findings on barriers to linkage are compared with those from a report of industry-higher education linkages across all UK universities in all sectors (Howells et al, 1998), a number of key differences are indicated in the barriers to accessing funding for those in this survey. The differences in fig 4.13 below appear to indicate first, that there is a reasonably high awareness and understanding of industrial issues and economic pressures in the oil and gas sector and, second, that unlike researchers in UK universities in general, researchers in this area find industry related research interesting and have fewer problems with differences in objectives.

Fig. 4.13. Barriers to establishing research linkages: comparison to all sectors

Rank	All UK Univs. / Sectors (Howells et al, 1998)	Oil and Gas Univ. Survey
1	Differences in objectives	Current O&G economic climate
2	Work needed by industry not interesting	Difficulties in making contacts with relevant organisations/ personnel
3	Difficulties in making contacts with relevant organisations	Timescales and goals
4	No influence on base line funding	Lack of confidence in universities
5	Insufficient equipment and facilities	Industry doesn't understand university research process
6	No influence on academic promotions	Problems transferring knowledge
7	Delay in publications	Lower industry priority of blue sky research than previously
8	IPR issues	Universities in competition with oil service companies
9	HEIs not seen as reliable	Ambivalent attitude to industry funding

Looking at the table in depth, the two largest barriers for UK universities in general are differences in objectives and the work needed by industry not being interesting. These relate to cultural differences between university and industry as discussed above. However, it is significant that these barriers are ranked below two others in the responses gained from this survey – those of, ‘the current oil and gas economic climate’, and ‘making contacts with appropriate personnel in industry’. Therefore, the

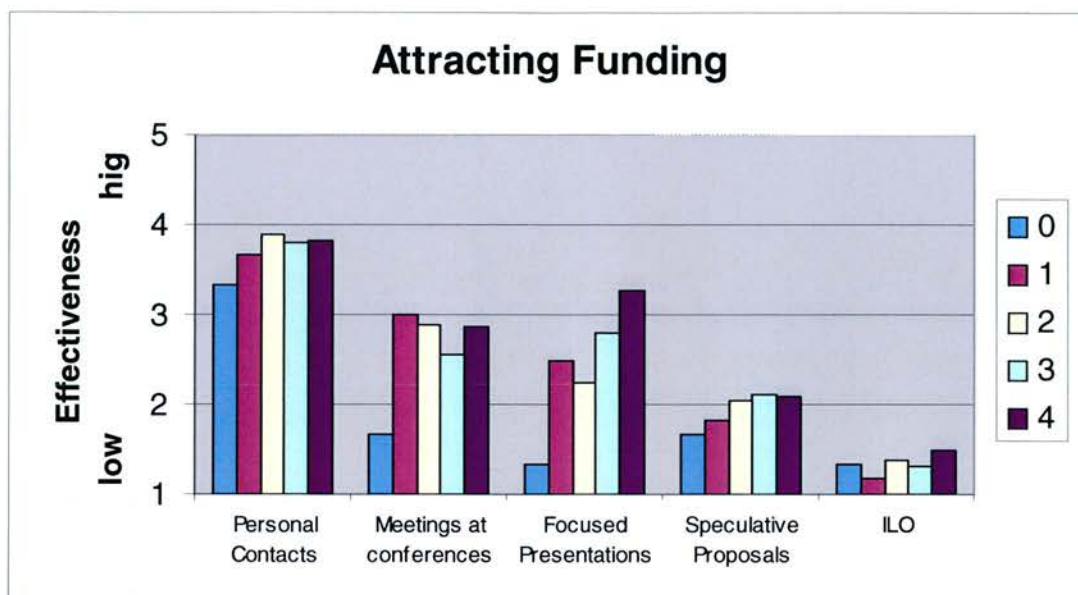
findings from this survey suggest that in this sector, cultural differences may be lower than the norm in the UK in general. This may be due to the high linking opportunities in the sector as identified by Salter et al (2002).

Also, the lack of equipment and facilities was noted as a barrier in the survey of all universities whereas the respondents from the oil and gas survey did not cite it as a problem. Indeed, although there may be resources lacking in the universities, there were instances where it was indicated that part of the benefits of linkage was to gain access to data or equipment provided by the company in return for the expertise of the university researchers.

4.4.2 Overcoming Barriers to Linkage

In response to the problems that universities have in obtaining funding for research, 65% of departments have in place of some form of departmental research strategy for obtaining research income. It is likely, as a result of the often vague responses to the simple question regarding the existence of a research strategy (e.g. “sort of”!), that the scope and extent of these strategies varies from a formal written document that outlines methods, expectations and best practice in gaining external funding, to unwritten, informal guidelines. Almost all respondents reported that personal contacts are the most effective method of attracting oil industry funding, with meetings at conferences and so on also useful (again this agrees with the findings from the literature discussed in 2.3.1). Speculative proposals and the use of industrial liaison offices were reported to be rarely effective, an interesting finding given almost universal existence of these in universities (Charles and Conway, 2001).

Fig. 4.14. Effectiveness of different methods of gaining sponsorship by linkage score. (n=40)



When the respondents were split into their rankings for low to high linkage activity (see figure 4.14 above), there were differences exhibited for gaining funding through personal contacts and in particular through focused presentations. The researchers with higher linkage activity had greater success using personal contacts than those of the lower linkers and found greater value in their use of focused presentations to industry staff. This could suggest that their increased activity in the field of industrially sponsored research enables them to understand more effectively the needs of the industry and also the scope and type of research that they are willing to sponsor (identified in the literature as a factor in making linkages work – see 2.6.1).

4.4.3 Working With Industry

The results in section 4.3 indicate that industrial research work is of considerable benefit and interest to university researchers. However, the findings from the survey also indicate that the working relationship between the university and industry is not entirely without difficulty. When asked if they felt that the university work was sufficiently monitored and directed by industry, although 60% of respondents were satisfied, the remaining 40% indicated that this was either not the case or that they had had mixed experiences of this. In addition to these figures, some of the

comments by researchers made in response to this open ended question indicate a level of dissatisfaction with the monitoring process.

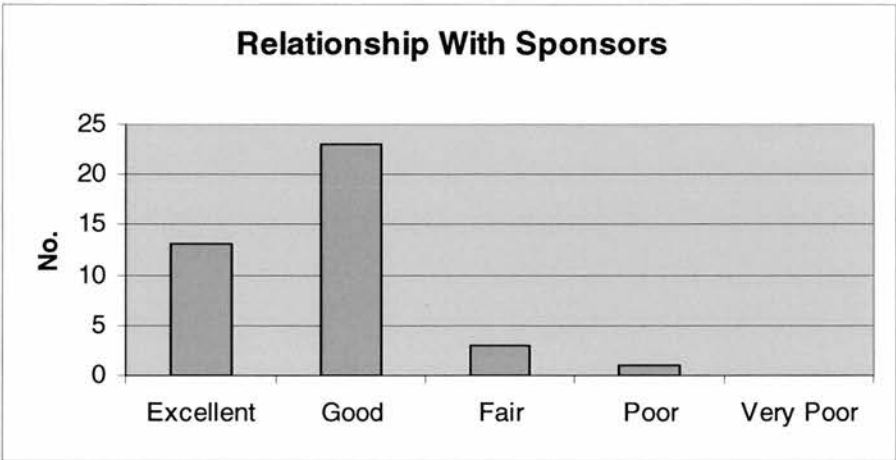
The reasons for their dissatisfaction with the monitoring process fall into three areas. First are time and resources related issues, with respondents identifying the limited external research budgets of companies as a barrier to providing enough time for monitoring (this is a barrier highlighted in the literature by Corsten (1987)). In addition, the typical two to three year timescale of academic research work (projects, PhDs and Post-Docs) can be too long for industry researchers to plan for, as industry work is often more short term orientated (as identified by Geisler (1997)).

Second, a number of respondents suggested that industry may underestimate the resources required to monitor and fully access the benefits of sponsored work. This applies not only to the level of in-house expertise in the company, important in being able to understand the value of, and to apply, new knowledge, but also to the amount of time allocated by industry staff. This highlights the need (as discussed in depth in section 2.2.2) to view university-industry linkage as a two-way process. This finding may suggest the flawed logic of the linear model (see 2.2.2) underpins some industry researchers' views of linkage – i.e., they view linkage as a one way process, with university providing knowledge for industry to use.

Third, the high turnover of staff in the oil sector means that the industry contact may not be the same throughout the course of the whole project. This can lead to problems, not only in terms of getting the new member of staff 'on board' the project, but also with changes of direction or a fall off in interest. This was particularly noted in JIPs (Joint Industry Projects) where there may be up to ten industry figures involved. A number of respondents reported instances in which the majority of industry figures are fully involved, alongside a small number who do not fully engage with the project. This staff turnover-related problem was highlighted in university-industry linkages by Webster (1994) and Dodgson (1996) and again reinforces the importance of interpersonal relationships for a successful linkage process.

However, even with these perceived problems, when asked to describe the nature of the working relationship with their sponsors, 90% of the university researchers believe that they had good or excellent relationships with their industrial partners.

Fig. 4.14. University researchers perception of relationships with industrial sponsors (n=40)



There may be two reasons for this apparent contradiction. First, the respondents may accept the differences in perspectives, needs and interests of the industry researchers and take these potential conflicts and issues on board as part of the package of gaining industry funding. This could lead to a resignation by university researchers that these research linkages will always be limited by the differing aims and attitudes of the two research cultures, producing relationships that are productive in terms of meeting the aims of the proposed work, but limiting the scope and potential of extending and enhancing the results of the work. Although the survey indicates that this sector demonstrates significantly fewer of the problems of this barrier (see 4.4.1), nonetheless these problems are still evident in university-industry relationships in oil and gas related research.

Second, some researchers indicated that although they expect input from their industry partners, they do not always want to be directed, but get ‘constructive criticism’, suggesting that there may be an element of university researchers that would rather conduct their own research without the input of their industry funders. This was certainly not indicated by all researchers in the survey as some reported

gaining much out of linkage interactions and the researchers may have different experiences due to particular instances of linkage.

4.5 Conclusions

This chapter has utilised a survey of university researchers to gain an overview of the nature of the university-industry linkage in the oil and gas sector. The primary aim was to gain an overview of the types and extent of linkage in the sector, along with information on the attitudes and experience towards linkage of the university researchers.

Individual researchers' responses were classified by a 'linkage score' relating to their level of activity in linkage in order to assess if the data could give any indication of 'high' or 'low' linkers (similar to the findings of e.g. Rahm (1994) or Santoro and Chakrabarti (1999)). This process revealed that although there was no clear split of high or low linking researchers a spectrum is present. Moreover, responses to certain questions in the survey revealed differences in their attitudes and experiences of linkage along this spectrum.

The range of linkage activity indicated by the responses in the survey showed, similar to the findings from UK university-industry linkages as a whole (Howells et al, 1998, Charles and Conway, 2001), that sponsored research in universities the most popular method of linkage (with 97.5% of respondents active in this area). Responses indicated that these projects involved both purely industry sponsored research and research that was funded jointly by industry and research councils. This again mirrors findings from this literature. There were a large number of projects (57%) that were funded by more than one firm (with a maximum of 20 companies involved). Information on the levels of these types of joint projects across UK universities in all sectors was not found in the literature. The presence of such jointly funded projects is perhaps surprising given the indications from the literature on the oil and gas industry (see Chapter 1) that there are high levels of distrust and adversarial behaviour between firms in the oil and gas sector (Bower and Young,

1995; Crabtree et al, 1997). The reasons for this could not be explored through the survey, but these findings are explored further in Chapters 5 and 6 of this thesis.

The survey data has demonstrated that the majority of the instances of research funding going into universities from the industry are coming from a small number of large oil operating companies and that the larger funded projects are going to those researchers with more linkage activity. The typical the value of research projects was £75 000 per year. No equivalent data was located on other sectors.

Of the other mechanisms of linkage, 70% of respondents were involved in industry funded PhDs, and 80% in consulting activity for industry. These findings from the survey reflected those in the literature (e.g. Corsten 1987; Faulkner and Senker 1995b; Harmon et al, 1997) that smaller firms are more likely to link through consulting rather than longer term sponsored research. Other suggestions from the literature that indicate the reasons for diversity in the extent of linkage were also found. Technological area (Faulkner and Senker, (1995b) differences were noted, with differences in the motivations for linking between geoscience and engineering researchers (who were more likely to be motivated by gaining new research ideas from industry). The finding that the highest funded projects were located at universities with specific oil and gas departments or reputations for oil and gas research also indicated that university related factors (Schartinger et al, 2002) influence the extent of linkage.

The findings relating to the benefits of linkages revealed some interesting differences from those found in the literature. Although the main benefit of linkage was to gain access to funding (agreeing with the findings of e.g. Charles and Conway, 2001 and Jones-Evans et al, 1999), other key benefits to linkage were found to be gaining access to data, getting ideas for new research and feedback on research from industry. This is in stark contrast to findings from the research on university-industry linkages across all sectors, where university and industry are found to have different objectives (Howells et al, 1998) or industry-relevant research was found to be 'uninteresting' (Lee 1996). Indeed, researchers indicated that the industry provides

‘interesting problems’ for university. This indicates that the sector is a better-than-normal location for industry researchers seeking to forge linkages with universities.

The research literature indicated that informal interactions are important both in generating and successfully undertaking university-industry linkages (see discussion in 2.4.1) and there is strong evidence that this is the case in this sector. Researchers with higher levels of informal interactions with industry were found to have the higher funded projects. Personal contacts were found to be the most effective method of obtaining funding, with speculative proposals and working through Industrial Liaison Offices ranking significantly lower. It was interesting to note that those researchers with the higher linkage score (the assessment of which included the level of informal contact with industry) found focused presentations to be markedly more successful than those with lower linkage scores. Higher linkers were also more likely to rank finding a contact in industry as the main barrier to linkage where low linkers ranked problems of finding mutually acceptable timescales and goals as the main barrier. This indicates that the level of informal interaction is directly linked to gaining an understanding of what industry wants – a key factor identified in successful linkage activity (Senker, 1990). Importantly, this indicates that those with the higher linkage score have a better understanding of the needs of industry, and as a result are able to tailor their research to meet the needs of industry. These differences are explored further throughout this thesis and are developed in Chapter 7.

The survey indicated that few had used ITF as a route to gaining funding, and that some would not attempt to use it. It is however, likely that there are some researchers with a low linkage score that may benefit from the organisation. Unfortunately, these are also the respondents that were not aware of the organisation. The researchers that were not keen to use the ITF indicated that they prefer to use their existing contacts with whom they had a good relationship. This again reinforces the importance of informal linkages and suggests that there is likely to be resistance to external actors forging linkages. This echoes Faulkner and Senker’s (1995b) finding that the best approach to generating linkages is through ‘dating agency’

mechanisms, where potential partners can get to know each other and allow trust and respect to build up between partners (Davenport et al, 1999).

The interface between the university researchers and the industrial sponsors was found to be, in general, very positive. A good working relationship between the two was perceived by the university researchers. However there was, from some researchers, indications of dissatisfaction with the lack of monitoring and input to research projects by industry sponsors, suggesting that despite the good relationship between the two, problems still exist between university and industry in this sector.

This chapter has presented the features of university-industry linkages through an analysis of a survey of university researchers. This creates a useful context from which to base a deeper investigation of these areas to provide a fuller picture of linkage in this sector. It is this which will form the basis of the next two chapters, through the examination of data collected through semi-structured in-depth interviews conducted with academics and industrial figures.

5. Types, Extents and Benefits of Research Linkage

5.1 Introduction

This chapter describes the extent, types and benefits of university-industry linkage in this sector utilising data gained from the interview research. This adds substance and depth to the basic characteristics of the research linkage described using survey data in the previous chapter. In doing so, the chapter will provide a detailed understanding of the workings of the different types of linkage and the associated benefits for those involved in linkages. Throughout this chapter quotations from interviews will be labelled either, UIx or IRy, to indicate that the informants were, respectively, university researcher 'x', or industry researcher 'y'.

5.2 Type and Extent of Projects

Informants from industry and universities described a broad range of types of linkage. These are summarised in table 5.1, along with the typical types of project deliverables expected or provided.

Table 5.1 Range of linkages identified by interviewees between university and industry in the oil and gas sector

Type of linkage	Typical purpose and expectation	Typical Deliverable
Sponsored Research	Long-term speculative research / long-term problem solving work through university knowledge and skills	Academic reports, theoretical developments, software models, working methods, case studies
Consultancy	Short-term problem solving	Models, information, short papers / reports
Sponsored Posts	Individual sponsorship for advice, PR, work etc.	Informal advice, recruitment, PR
Sponsored PhDs	Research and recruitment	Theoretical developments, recruitment
TCS	Product development through university knowledge and skills	Enhanced product or process

The interviews corroborated the findings of the survey in that there were no instances reported of projects that involved a significant research input from the industry partner that could lead them to be described as anything other than sponsored

research (although as described in this chapter, industry partners contributed much more than funds to these projects). However, some informants reported that ‘joint’ research occurred in a small number of cases in the sector. Unfortunately, representatives of these projects could not be located in the time frame of the research.

5.2.1 Sponsored Research Projects

The interviews revealed that sponsored research projects were the most common form of linkage occurring between industry and university in this sector. These were described by the informants as being similar in format to a ‘traditional’ university research project in that they tended to last two to four years, were run in the main by the university researchers and were based in the university. This type of work was described as ranging from large scale projects involving researchers from a number of universities and large research groups investigating various aspects of an area of investigation, to smaller one person projects focusing on a specific area. Informants reported that projects tended to be managed on a day to day basis by the academics with ‘steering meetings’ perhaps twice a year to provide an opportunity for the industrial sponsors to receive formal feedback and to shift the research direction in ways that may be attractive to them.

Informants descriptions of projects identified some variation in the types of research being undertaken. This ranged from research-focused work in areas that may have an influence upon the work that industry was undertaking, to more industry-focused research that was more closely aligned to a problem identified by industry. This was reflected in the range of possible deliverables described in table 5.1, from academic style research reports to theoretical models and software that could be more directly applied to industry in others. This distinction was not clear cut but is reported here due to the differences in research outputs across the projects studied. This range of deliverables reflects the finding in 4.3.3, that university researchers identified two routes through which they tailor their research to the needs of industry – by pulling out the implications of their research findings to industry, or by searching out problems that industry need to be solved.

The outputs of sponsored research were reported to be typically academic in nature- developing theories, models, algorithms and so on for understanding processes. In the majority of cases, the outputs or 'deliverables' were simply in the form of academic papers or academic reports that are tailored for industry audience. In some cases steps were taken so as to make the findings more useful to industry through, for example, the sharing of software that may be produced to utilise new theories or algorithms or new analyses utilising real field data. The university researchers typically made their outcomes accessible to industry staff through university websites and dissemination at project meetings and conferences. However, in a smaller number of other cases, specific models for more direct use by industry were developed as key project deliverables. The following two examples, taken from different universities reflect this.

The excerpt below is from a research proposal to industry provided during the course of a research interview with UR12, from a geo-science department in a pre-1992 university. This shows a limited level of tailoring of outcomes away from typical academic outputs.

Deliverables will comprise applicable models in report and poster format, delivered via in-house visits, secure Internet routes and CD reports. The core component of each research theme will go ahead as long as the minimum level of number of sponsors has joined the consortium.

1. Sponsors meetings will be held spring 2002, 2003, 2004
2. A sponsors website will be hosted [at the university]. This will be secure and requiring password access, and will be used to:
 - disseminate new results - increasing the period of time the sponsors have to look at the results
 - host a billboard showing current research activities
 - host electronic versions of the Phase 1, 2, 3 reports, and of any interim reports...allowing individual workers access to results
3. Sponsors may request at least one in-house visit per year if they require an oral update on results, require an independent opinion on a particular prospect, or would like an outside presence at an internal conference or workshop. Expenses will be in addition to consortium membership.

As can be seen from the description of the deliverables described above, the focus in this (and the majority of sponsored projects described by respondents) project was upon making the results of the research accessible to the sponsors through forums such as meetings and websites, rather than tailoring them to particular industry goals.

This second example shows more industry focused deliverables and is from the website of a specialist oil and gas department of a post-1992 university.

The use of web-based deliverables in Phase 1 will be extended and continued during Phase 2. This format is thought to be the most practical and most easily used by sponsors. The deliverable material will include:

- Web based reference catalogue
- Prior well test and seismic models
- Prior well factors
- Well test planning methods
- Case studies

This web based material will be constructed to assist in the training and the technical transfer of the research.

These differences reflect the range of possible deliverables to industry of sponsored research described in 5.1 above. It is interesting to note that the more industry focused deliverables were from a specialist department in a post-1992 university, reflecting the indication in 2.4.3 that factors related to the university environment can effect the extent of linkage.

Informants indicated that in most cases the additions of knowledge from sponsored projects did not produce an entirely new tool for analysing geological data, but contributed towards 'reducing the error bars' of an industrial examination of an oil field or provide an alternative perspective on the way certain things were viewed. In many cases it was reported that research projects still had potential to yield more information at the end of a typical three year phase and often research projects continued (through continued sponsorship) into 2nd, 3rd or 4th phase funding. This allowed academics the opportunity to fully develop ideas or extend their research groups to include additional staff and enabled industrial sponsors to direct research

into areas that they felt could be more interesting. This reflects a development of understanding and trust between partners in linkage to allow linkages to be developed to mutually agreeable goals. Trust and communication were identified in the literature as important aspects in successful linkage (Senker, 1990; Dodgson, 1993) and relationship building was demonstrated as being effective in these cases. These themes are developed further in the next chapter.

The projects were typically academic in nature, but of interest to scientists in industry and informants from both university and industry indicated the source of ideas for projects can come from both sides of linkage. This demonstrates the non-linear nature of research interactions (as discussed in Chapter 2) and that in this sector both university and industry are contributing to sponsored projects. Two typical and contrasting examples of this are described below. In the first example, a university researcher describes how a project was instigated by a problem that the industry was having.

It was an amazing situation, people in the company were producing diametrically opposite models for volumes, connectivity etc. so they needed new techniques to work it out. It's a 2 year project to understand mechanisms and predict certain things from data in different companies – but it is a generic thing – we are not going to have people producing full field models of particular fields for a company, no that is not what they are sponsoring, it's blue sky, with brilliant data. [UR10]

The researcher highlights the fact that the project is not a piece of problem solving or consultancy work for a company to solve an immediate problem. The project was still to be run and managed at the university, and run as a basic research project, yet it shows the importance of a useful dialogue between university and industry in selecting suitable and useful areas for collaborative investigation.

The second example below describes a project instigated by the university researchers who then sought to gain funding for the project from industry. Their experience in undertaking more applied projects drove them to undertake a more theoretical project that could be of longer term use to industry and of more interest to the researchers academically.

...we had got fed up of doing direct contract projects, which was that people had rung us up with data that they couldn't handle and said could we analyse that for them...So the idea with

setting up this one is that it is quite focused on theoretical developments and it doesn't have a direct obvious product - although we do give them the software that we develop. Although to be honest I don't think any of them can use it. It was to give us a broader base to develop the theory so it could be applied to new data sets as they came in but – so we had a kind of menu of the things that we wanted to do and they [the industry sponsors] focused it a little bit. [UR6]

These two methods of tailoring projects again emphasise the two strategies that university researchers used in making their research attractive to industry sponsors (as described in the survey in 4.3.3). One obtaining information from the industry to generate a research project in an area of need and the other shifting the outputs of their own interests to suit industry sponsors. The second researcher highlights the fact that the outcomes are much less likely to be utilised by industry, but would provide a better understanding of the fundamentals of the area which could be of use to industry in the longer term. An industrial sponsor of this particular project describes their expectations and motivations for joining this Joint Industry Project (or JIP) below.

It hit the desk here 4 years ago, people had heard of it before because it had grown out of another project, so people vaguely knew about it and the people were that were doing the work. Knowing people is important. They were proposing work in a trendy area, at the time the people were looking for projects to fund and people spent their budgets as there was a surplus of money – so it got funded, a few years later and it would have struggled. But a lot of these projects have been going about 15 years, once a project has got momentum, sometimes it is more easy to carry it on than stop. In a way, it is good that we fund these things for a long time, talking to people that have been involved in these projects, it is often the one that's getting funded for ten years, then you get the results, it is fairly rare to get results after 3 or 4 years. [IR1]

The sponsor accepts that this project, in line with many projects of a similar nature, may not get results in the near future but highlights some key aspects of collaboration in these types of projects. The industry sponsor was attracted to the work because it was, at the original time of funding, a 'trendy area', that is one that industry thought could lead to advances in the future, or could be the next big step in the way this particular sort of phenomena was examined and understood. The work is speculative, but was funded because the economic climate was such that research budgets in oil companies were high and therefore there was more money for speculative research projects that have a low chance of direct impact. The sponsor also highlights the importance of contacts in building these linkages, an important factor in linkage identified in 2.4.1, and will be further investigated in Chapter 7.

Typically informants indicated that these types of project were not sponsored by a single company, but often involved a consortium of companies that oversee the project as a 'steering group'. This form of sponsored research (a Joint Industry Project, or JIP) created an environment where there may be up to 12 companies supporting a research project. This resulted in a situation in which, for example, there may be pressures to take the research in different directions, or to demand particular services that can not be supplied to all members of the consortium due to the time restrictions of the researchers. However, informants from both university and industry reported that in the vast majority of cases these factors are not a problem. Indeed, informants suggested that the long term nature of this research meant that there were no real problems in terms of any particular company sharing knowledge. Companies were happy to be involved on the same projects as competitors as they did not see the role of this work as gaining a competitive advantage over the others, but improving competitiveness across the whole industry. Indeed, one industry researcher (below) commented that the JIP system was an extremely useful mechanism, as it enabled companies to work together in an environment away from commercial pressures.

That is where the JIPs in fact are quite useful because they do offer a platform by which operators of oil companies, certainly all the major contractors if they choose to join, can actually communicate on a playing field, which is separated from, to a reasonable extent, from their normal day-to-day commercial interactions. So it produces a mutual ground, which enables you to communicate in a far freer way than if you would, for example, when you're talking in a particular joint application where, inevitably, you have got your own commercial agenda [IR7]

In suggesting that JIPs help to break down the distrust that has been evident in the industry (Bower and Young, 1995), this informant reports a situation that was not expected at the outset of this research. Indeed it was expected that due to the distrust highlighted in the sector (see Chapter 1), that opportunities for linkage and knowledge sharing could be threatened but this was found not to be the case.

There were of course some cases where individual sponsors fund an entire project, and these can lead to closer working between the industry and university over the projects and the outcomes and deliverables. Opinion of the university researchers was divided over a preferred type of linkage, some indicated that they liked to work

closely with a sole partner, others felt that close working with sponsor could affect their academic freedom as they may be steered too strongly.³

One of the major advantages to both sponsors and academics of JIPs was the volume of research that can be produced by the relatively small contributions of sponsors. The interviews confirmed the survey findings that typically the yearly contribution of a company ranges from £15 000 to £30 000. This is a small amount of money to international oil firms, but university informants indicated this as a standard 'buy in price' as it was perceived by them to be the level of funding that can be accessed from an industrial departmental or section budget. This made gaining funding much easier as contacts in companies can provide this without having to go to a higher level of management. Therefore it was easy for individual industry contacts interested in particular projects to fund universities in this way. In addition, for the university researchers, this meant that if they could get enough companies interested in their research they could gain a large level of funding relatively easily. With this in mind, projects were often initially set up very flexibly in terms of the scope and number of staff that will be employed on the project, as the following example from the research proposal supplied during the interview with UR12 shows.

...The minimum number of sponsors for the project to be viable is three. This covers the costs of employing Dr. [x] full-time, plus associated running costs, and should support the involvement of other principal investigators. In the event of additional sponsors joining the project, the phase 4 programme will as follows:

5 sponsors: 1 years salary for Drs.[y,z]; extra travel and fieldwork, and lab cost support for Drs. [a,b]

6 sponsors: 1.5 years salary for Drs.[y,z]; fieldwork and lab cost support for Drs. [a,b]; 1 lab-based PhD project.

7 sponsors and above: further salary support and extra research student.

As can be seen, the level and scope of these projects can be greatly extended simply through a large volume of sponsors all offering a small amount of funding, which can lead to the employment of a significant number of research staff for a university

³ These attitudes and perspectives will be extended further in Chapter 7 of this thesis.

department. This effectively meant that a company obtained, for example, a £500 000 research project for an outlay of £25 000 over three years, so it can be seen as good value for all sponsors if additional companies are involved. Informants reported however, that the large number of mergers in the oil industry in recent years has caused some problems for the university researchers running these forms of project. In some cases three separate sponsorship contributions became one, as three of the companies on a project have merged, and a large number of university informants reported problems in terms of completing the current project with reduced budgets. This also meant that there were less companies to fund new projects, again making it more difficult for research projects to be wide ranging due to budget restrictions caused by fewer potential sponsors.

5.2.2 Sponsored Posts

An alternative method for industry to gain access to university knowledge was through the direct sponsorship of an individual researcher. This type of linkage only applied to a small number of the informants and they reported that this form of linkage was less direct and less likely to be based around a particular problem, although the funded researchers had particular areas of expertise. The key reason for funding such a post was identified by the informants to enable the company to call on the researcher for advice and expertise. Also important in these types of interaction was the utilisation of the university researchers as filters for recruitment and to recommend to their industrial sponsors students that may make good employees. Therefore PR was found to be an important element in these types of sponsorship, as one industry sponsor puts it,

We have another budget for the softer returns [such as sponsored posts] - the good citizenship budgets or something like that...whether it is to divert students up here for bits of research, to learn something about his students. It is not what I would call technological development money - it does not have an easily measurable return. [IR6]

Industry researchers reported little expectation in terms of concrete deliverables in this sort of linkage. As a result, these posts are relatively rare, and a number of the university researchers suggested that these posts are now harder to come by as a result of the financial problems in the oil industry in recent years. Indeed, one

researcher who was in an ongoing funded post felt that there was little chance this sort of post coming up in the current climate, and felt fortunate that it had begun when the oil industry was in a very healthy financial state.

5.2.3 Sponsored PhDs

Informants reported that industry sponsors a large number of PhD students through their studies. These occurred as independent programmes or as part of a larger research collaboration through which a part of the research is undertaken as a PhD project. The PhDs were often funded through the CASE studentship scheme. The scope of the research produced by the PhDs was thought unlikely to have a great impact upon industrial practice and, as with the sponsored posts described above, informants did not expect most of the end products of these linkages to be of direct use to the sponsors. They were however, reported to be a common method of recruitment for potential staff to sponsoring companies and the meetings between students and sponsors throughout the projects gave industry figures opportunities to assess the capability of the student. In addition, most informants felt that this sort of linkage provided a cheap way for industry to gain access to the researchers in universities (through liaison with student supervisors) and could act as a precursor to a larger form of linkage, such as consultancy or sponsored research projects. This again highlights the importance of building up relationships and the importance of informal links – themes discussed in the next chapter.

5.2.4 TCS Schemes

The TCS scheme (now re-launched as Knowledge Transfer Partnerships) involved a university employee (the ‘TCS associate’) working full time in an SME on a research related project to improve a product or process. Involvement in the TCS scheme was only reported by those researchers in engineering related fields. Indeed, almost all the earth science academics that were spoken to in the course of this research had not heard of the TCS scheme, whereas engineering academics were experienced in and positive about this form of linkage. The nature and goals for this sort of TCS made it unsurprising that the linkages tended to be with engineering related departments. In

these cases the research was focused on an artefact, rather than earth science departments where the focus was much more likely to be purely theoretical and where linkages were typically with large multi-national companies.

Informants suggested that despite its suitability, it was not a well known method of linkage by SMEs and university informants indicated that TCS was often suggested to potential sponsors who were unaware of the scheme previously. University and industry informants suggested that SMEs in general found it difficult to instigate linkages with universities. This strongly echoes findings from the literature (e.g. Corsten, 1987; Shane, 2002).

In the typical case below, the industrial partner in a TCS scheme describes how the development of a technology reached a point where more basic research input and expertise was required to take it further.

It is all very well, we can do little tests in the well across the road here, in the real life situation where you have strange situations, with deviated wells and horizontal turns and you are pulling or pumping through a pipe - what are the dynamic effects on the adjacent interconnected pipes - so we want to look at that and it is fairly fundamental - this specific piece of work we are giving to the university as the TCS. It is fundamental knowledge in an area which may, if we don't do it, cause problems - or limit the marketing of the product. It is a questions that we need answering - because customers need the answer - customers may ask what about this and we need to know. TCS is not wait for two years and get an answer, it is interactive, and hopefully in three months time we will have enough to be able to start to steer the thing and get early results. [IR4]

As the TCS associate was working on site, the results and expertise were fed straight into the company and the work was tailored to suit immediate and longer term needs. The linkage therefore promoted a high degree of technology transfer from the university in the form of development of the artefact and also in the skills and practices of research and development that were not existent in the company.

5.3 Benefits of Linkage

University-Industry linkages in this sector were found to bring a number of benefits to the university and industry partners involved. The prime goals (and therefore benefits expected) of the university and industry informants echoed the discussion in 2.4.3 that universities gain research funding to develop research ideas and

publications and that industry seeks to improve competitiveness through enhancement of knowledge. These basic needs underpinned all university-industry linkages explored in this thesis but by no means were the benefits of either party restricted to a research paper or knowledge leading to better products or process. This research found that the range of direct and indirect benefits to both parties was extensive, and the core benefit to arise from any particular linkage was not necessarily of any one particular type or indeed be the kind intended at the outset of the project. This concurs with Scott et al (2002) who indicated that the benefits of any particular instance can be unexpected or indirect.

In the following sections I will describe the different benefits to both university and industry in turn. These benefits will be split in to direct benefits negotiated at the beginning of the linkage and indirect benefits which arise and may or may not have been integral to the linkage mechanism.

5.4 Direct Benefits for the University

The direct benefits for the university in undertaking linkage in this sector identified by the informants comprised, publications and research funding, generation of ideas, data for research and aids for teaching. These will be outlined in detail below.

5.4.1 Publications and Research Funding

University researchers reported three fundamental goals in their work, generating new research ideas, new research publications and external research income to enable this research work to be done. This research money was used in a variety of ways by the university researchers, from funding themselves and other staff to providing expenses for their research. In addition, university staff reported that it is increasingly common, particularly in more applied academic environments (e.g. specialised oil and gas departments), for research staff to be dependent on generating external funding for their academic positions to be maintained. In such cases the university researcher's very employment, or at least that of some of their staff, depends upon

their ability to obtain and maintain a level of research sponsorship, making the maintenance of these relationships of great importance to them.

In addition, the RAE (Research Assessment Exercise) system of allocating funds to university departments uses publications as a key measure of the quality of the research carried out in a department and therefore the funding they will receive (RAE web-site <http://www.hero.ac.uk/rae>). However before they can generate publications, researchers need money to develop the quality research from which publications can be drawn. The following quote from a university researcher reflects this situation.

ultimately what I want is publications, because there are two main ways in which we are judged in terms of our research - publications and money you bring in - yeah the money is nice but the industry funding is necessary to do what I want because on of the things that I am very keen on having is a group of people - now my research group has been primarily composed of PhDs but it has been very successful [UR8]

In addition to the need to fund themselves, the researcher above describes the importance of having a research group around him, which the industrial funding enables him to create and maintain. Although this may not be the case for all academics, some reported that the generation of academic research output is helped by working in groups rather than in isolation. This building up of research groups not only provided an environment where research ideas and outputs could be shared and developed, but also helped to build up the reputation of a department as a centre of excellence in research or as a centre that is closely allied with industry. This in turn can assist university informants in gaining more funding for the researchers as the department became more attractive to industry.

Many informants stressed the importance of industrial funding in providing resources and equipment that could not be purchased with government funding alone – as this funding had to be more tightly accounted for. This resource was also often used to provide an additional resource for the departments, such as topping up other research funding pools or providing expenses for travel and dissemination of research. A typical example of this is demonstrated by the following university researcher.

...they are sponsoring two projects in the order of £20-25 000 per year but they give us £100000 – so 50k is flexible money for us – it helps to buy equipment, hire RAs, it may be that the academic staff do that work – so it becomes profit to keep the place going. [IR11]

The two key funding benefits to the university informants therefore were, first, that the industry funds complement the scarce public funding available and second, that it can be used more flexibly, greatly assisting, for example, the development of research groups or improving equipment. This demonstrates that linkage in this sector is motivated in similar ways to other research linkage in the UK across all sectors (Scott et al, 2002; Charles and Conway, 2001), yet there were benefits identified, such as idea generation for projects and interest in working on projects that are relevant to industry, that were not reported in the research on other sectors. These benefits are discussed below.

5.4.2 Idea Generation for Projects

The money obtained from industry sponsorship and public funding enabled the researchers to undertake the research to produce the publications that they require. However, in some cases industry linkage was more productive than publicly funded work as it not only provided the researchers with the capability to undertake a research project, but also contact with industry gave stimulation and ideas to suggest new research topics. As described in 5.2.1, projects were typically run and managed predominantly by the university researchers but the ideas for these came from both sides of linkage.

For example, an engineering firm may seek university expertise to address the problems that may occur in the development or understanding of an artefact. Equally university informants also gave evidence of using the information gained from industry contacts to suggest new areas of research to be supported by industry. The university researcher informant below describes this process below.

I am always fascinated by finding out what people need, it's fundamental to what I do. In university research you need to find 'what is the need?' – you could spend your whole career on a piece of research and then take it to industry and find that the chances are that no one is interested. [UR7]

In addition to projects created from scratch, work conducted for industry also provided new areas of interest spinning off current linkage activity that formed either industry or independently funded work. These new scenarios of research work also

provided the researchers with areas of investigation that they would otherwise not have looked in to. The university engineer below describes this as a common occurrence.

There will often be side issues that will spring off. There have been a number of cases that on the back of TCS programmes, we have applied and successfully been awarded EPSRC research grants, as we have taken one particular issue and said that there is a real fundamental issue that needs to be investigated here. Nothing really to do with the company, but we have seen an important issue and turned it into a full blown academic programme. [UR3]

The transfer of research ideas was therefore a key benefit for the university in this sector. Indeed most informants at least found that if they did not get their ideas directly from industry, found it easy to gain industrial outlets for their work. This result confirmed the findings of the survey that industrially related work in this sector of great interest and benefit to university researchers. This finding agrees with that of the survey, and is in contrast to the findings from the literature (e.g. Howells et al, 1998; Charles and Conway, 2001) which strongly indicates that in UK university-industry linkages across all sectors a key barrier to linkage was that industry did not provide problems that were interesting to university research. This suggest university research in the oil and gas sector is unusual in this respect. It is important to note that this finding was confirmed by both informants from industry focused departments (where this response could be expected) and from informants in non-industry focused departments.

5.4.3 Data for Research

Most informants reported that one of the most important benefits to come out of linkages is the data provided by industry. This was reported in all disciplines as a major benefit of university-industry linkage.

University researchers reported that utilising real data provided by firms is a great help in researching and developing theories. This real data, for example, ranged from seismic imaging data of areas that may potentially contain oil reservoirs for geophysicists to analyse, through to information on wave size, force and volume for engineers to utilise to analyse the safety of existing offshore drilling structures. Informants reported that this was a benefit as the quality of the data being provided

by industry was often of a much higher standard than that which the universities have been able to access independently. As a consequence of their need to obtain more and more accurate information on the resources that the industry was potentially accessing, companies invested in more and more advanced technologies to gain, in the case of seismic imaging data, as much information as possible on the makeup of the areas that may contain oil reserves. It is with this advanced data that the universities developed their understanding and theories.

The data in the industry is more than we could ever hope to image - all of the academic models that we produce from the sections of rock are inadequate to show the variation that we can actually see on the seismic [data, provided by industry] – they are too simplistic now - they give you a good in the head model for the youngsters who are just learning about geology - but it doesn't tell them about reservoirs. [UR10]

Research staff at universities also gained the benefit of feedback from their industrial sponsors when undertaking research linkages. The normal method of feedback of academic output is through peer reviewed journals where findings are assessed, and disseminated to other academics. Researchers involved in university-industry interactions in this sector also indicated that they want, and are required to publish, but the additional feedback from a industrial environment helped to shape and enhance their work in ways that would not necessarily come from the traditional methods. The importance of this industry data, and feedback and verification of research again emphasises the two way flow of knowledge within university-industry linkage in the sector discussed in 2.2.2.

5.4.4 Teaching Benefits

University informants also indicated that teaching in universities was assisted by linkages with industry. The generation of funding for projects often did not limit itself to funding a researcher on a project, as mentioned above in 5.5.1. One of the benefits was in enabling PhD students to be funded, who were not only to be trained in research, but also to undertake research that could range from the core of a sponsored project through to being a small side issue to a central work. Informants reported that from these student based projects larger areas of investigation had been identified that formed the basis of larger scale linkage projects.

In addition to these benefits, knowledge about industry technologies and working practices were utilised by some informants as teaching aids for both postgraduate and undergraduate teaching. Particularly in the engineering related disciplines, informants reported instances of linkage that resulted in, for example, industry technologies being provided for and utilised by both staff and students. This was beneficial both to the students who received training on projects that were directly related to an industry that they may well move into and to the staff who were also helped as it provided a greater depth in their teaching. A head of an industry focused engineering department describes this below.

...it greatly improves our teaching if we can actually say - here's an example of a technology that is in industry and we can use it as part of our teaching - so we might be doing experiments on a novel technology, so we say to student that we are doing this for this company and they want to know about whatever. On occasions we have managed to get spin off projects which the students can operate on. [UR5]

It is likely that students involvement in this way increased the credibility of the company in the students' eyes, making it more likely that they will see these companies as attractive prospective employers, improving graduate recruitment for sponsors.

5.5 Indirect Benefits for the University

Many university respondents stressed the informal benefits of university-industry linkage in terms of gaining and maintaining a network of contacts. Such networks provided the means through which funding for projects can be extended and opportunities for consulting work arise. This confirms the importance of informal linkages for these activities as identified in the literature (e.g. Faulkner and Senker 1995b; Davenport et al, 1999; Rappert et al, 1999). Informants reported that this was of particular importance to those researchers who need to generate external research income in order to maintain their research positions .

On a personal level, some university researchers reported that they gained immense satisfaction through the applied aspects of their work. Linking with industry provided the informants the opportunity to have a direct, important and financially beneficial impact upon the work of the sponsoring companies. Some researchers suggested

that, in addition to the academic output of research publications, making a positive impact in industry was personally extremely satisfying. Indeed, some informants reported that the work of value to industry sometimes gave a level of satisfaction that would not be obtained without the industry input. This helped to explain why some researchers end up working in the industry related areas of their science.

I am a researcher in petroleum engineering not theoretical physics – what you want to do as a researcher is to have ideas that change the way you view something, so there is no doubt, you ask any researcher, they get lots of money to make their job safe yes, but that is not really what motivates them, everyone wants an opportunity to produce genuinely new ideas and make an impact for the industry - there is no doubt about it. [UR14]

The work of informant above was fundamental research, rather than applied work, indeed he stressed later in the interview he did not want to undertake consultancy-style work and was concerned that his research group did not get pulled away from traditional academic objectives by sponsorship. However, his perspective upon university-industry linkage was shared by a number of university the researchers interviewed, that although they classified themselves as academic researchers, their involvement and satisfaction from working with industry was an important part of their work. Conversely, other researchers involved in linkage seemed to align themselves less closely to industry. These differences are consistent with the findings of Rahm (1994) and Santoro and Chakrobarti (2002) who identified differences in researchers linkage behaviour and attitudes with industry. These themes are explored further in Chapter 7.

5.6 Direct Benefits for the Industry

The direct benefits for industry in undertaking linkages were found to be primarily in gaining access to the research capabilities, including new information, methodologies, advice and assistance held within the universities. This finding echoes those of Faulkner and Senker (1994) and Salter et al, (2002) as discussed in 2.4.3.

5.6.1 Research Findings and Expertise

Industrial informants reported seeking academic research expertise to help develop an artefact, enhance understanding of a phenomena, or provide advice and input to a technological or scientific process in an industrial setting. These benefits are all directly related to academic research, although the tailoring of these benefits varied from project to project, as outlined in the sections above.

Informants (particularly university interviewees) reported that in many cases the monitoring and take up of these deliverables by the sponsoring companies was not consistent. In the case of the sponsored research projects described in 5.2.1, many university researchers indicated that sponsors at times seem disinterested in the research. It was suggested that this may have been a result of the long term and speculative expectations of the sponsoring companies, when entering into the projects. As a result of this, university researchers found the attitude towards linkage and the outcomes of the sponsored university research to be very relaxed, as the following response from a university researcher illustrates:

...there are deliverables, they are written down we like to tick them off but if you don't quite make one generally it is not a problem. [UR11]

In a large number of cases, the industrial informants reported that the sponsoring oil companies choose to pursue this long term, high risk research through sponsored projects as shorter term work was undertaken by their own internal staff. In these cases the companies were not looking for a piece of research which will guarantee an enhancement to their business in the short term, but something which may improve their productivity a great deal in the future, but is less likely to succeed. This is described by the industrial sponsor below.

Now if it was something that was gonna give a result in 12 months I would argue that I could go out to a contractor and buy the process today. We are not looking to buy something off the shelf we are looking to buy something that doesn't exist. A similar sort of convoluted logic applies to the probability of success – if there is a 100 % probability of success then that is not a technology project – we are channelling money out of this budget that is slightly more risky and more longer term... the minimum you expect it to save you is one well, the maximum, now the maximum could be much more than that. But you have say a 1% or 10% chance of it being successful. [IR1]

However, in linkages with smaller firms that do not have the budgets to undertake such long term research, it was reported that the projects necessarily had to have an impact upon the business. Although there was an understanding that in going to a university to gain research expertise through a project based linkage, basic research will be undertaken, there were still pressures to produce work that will impact upon business quickly. This highlights the differences noted in the literature (see 2.4.3) that smaller firms linkage is on a smaller or more short term scale than larger companies. The industrial manager of a small firm involved in a TCS scheme describes below these pressures.

[The research is focused upon] fundamental knowledge in an area which may, if we don't do it, cause problems - or limit the marketing of the product. It is about questions that we need answering - because customers need the answer - customers may ask what about this and we need to know. I'm sure its not, TCS is not, wait for two years and get an answer - it is interactive. Hopefully in three months time we will have enough information to be able to start to steer the thing. [IR4]

These sentiments were echoed by some researchers in universities, and that their research was affected and outcomes changed by these commercial pressures to the benefit of the sponsoring company. However, this was reported to be to the potential detriment of the university research output, as research that is publishable may not be produced due to the short term demands of industry.

a three year research project here is probably much closer to the operational needs of the industry...sometimes we look a little bit more like massive consultancy projects. [UR9]

This was a remark from the head of an oil and gas related department, that had pressures to generate income to maintain staff and therefore had to tailor research for industry, but who was also aware of the pressures to produce research literature for the RAE.

The informants reported that the variety of direct deliverables to companies ranged from the traditional academic outputs of reports, papers and theses, through tailored reports that may give assistance to the sponsoring companies, to informal advice and expertise on a particular area, or something more applied such as some data analysis or computer software. The different nature of these outcomes depended upon the nature of the linkage and its relevance to the needs of the company, the company

strategy with regard to any particular piece of external research, the type of university researchers undertaking the research and their willingness to provide outputs that are more relevant to industry.

At one end of this range, some university informants reported that they were more or less left to undertake their research free from the interference and guidance of industry. There is evidence from both university and industry informants that some projects were funded to a certain extent through altruism, as those who have been through the academic system and are now in industry, are repaying the system that educated and trained them. The deliverables were as a result left in a the traditional form and sponsors were satisfied that they are associated with what the informants felt is 'good science'.

for the most part oil companies ... let us do what we want -as long as we are producing the publications, are presenting at conferences so we have got a high profile they say "well that's good we are associated with that that is good for us it is PR in a sense" - it is good science too. How much it trickles down into their own science – I would say not a great deal. [UR8]

Other university researchers indicated that they tailored their work to be more relevant to the problems of industry. This research was not directly related to an existing specific problem, but offered insights into particular areas of knowledge and understanding of a range of phenomena. The purpose of this was to assist industry scientists in their understanding, and enable them to approach problems with new or different perspectives. This was thought to be important to the work of industry scientists who have little time to step outside their existing procedures and techniques to try and improve their way of working. This is described by the university researcher below.

It was to produce a series of illustrated geological scenarios, which maybe they don't know much about, and from that they could choose their own areas of interest, in terms of how that might apply to field that they are working on in the North Sea - its an educational thing. [UR10]

Researchers also created web sites specific to research projects to facilitate the dissemination of their research to industry and reported that these were effective. Others reported generating software as an outcome, for example as a method of utilising new algorithms that have been produced to understand geological

phenomena, and university researchers took steps to ensure that this technology was both available to, and understood by, their sponsors so that it could be incorporated into existing industrial processes.

Despite these pressures to tailor research, it was interesting to note that it was often reported by both university and industry interviewees that the sponsors, and others within their firms, had little time to absorb the information that was generated by the universities. These responses did however show the importance of the networking and trust between partners in linkage, as the research revealed that projects are often funded as a background activity, that may be of interest to those that sponsor it. These issues are developed further in the next chapter.

5.7 Indirect Benefits for Industry

Although the industry funders' main reason for linkage was likely to be based around one particular project, problem or idea, there were a number of indirect side benefits that added value to any member of industry involved in university-industry links. These indirect benefits to industry were often as important to sponsors as the direct benefits described above. They comprised informal expertise and advice, research and development management expertise and recruitment. These are described below and again reinforce the importance of the informal network that exist alongside the core linkage activity as a route to gaining benefits, echoing these findings previous research (e.g. Harmon et al, 1997; Schartinger et al, 2002; Bozeman, 2000).

5.7.1 Informal Expertise and Advice

Many university researchers reported that they were utilised by industry as a source of informal knowledge and expertise for issues that may not have any direct relevance to the project, and this was often perceived be of as much benefit to the industry sponsors as the projects itself.

Informants from both university and industry reported that it was often the case that the most effective knowledge transfer occurred whilst discussing matters not directly

related to the ongoing project or even the field of research, as described by the industry researcher below

I have no time really to read papers...we went over for a symposium and we were listening to papers from 8 till 5 but to be quite honest the main benefit was in the bar in the evening time – what are you up to and so on– its that informal networking that keeps you in touch with what's going on. It happens between us and the universities, and it is the off the record conversations etc. [IR1]

Informants identified a range of informal tasks carried out outside of these meetings, for example asking for a different impartial assessment of piece of work or problem for the industry contact, and asking for an academic investigation into a particular phenomena that may require knowledge of the academic literature, that would not be present within the company. This type of informal interaction was not reported by all interviewees, indeed some researchers did not receive this form of contact from their sponsors, or did not wish to be distracted from their main work. However, this sort of work led to a great deal of consultancy work for some researchers. These researchers gained not only additional income but also help for their teaching programmes through small projects for students and opportunities to undertake larger sponsored projects, as described by the university engineer below.

They want me to do this and write a report...within half a day I had unearthed a major report and two other papers...I have persuaded them to give us a sheet of this stuff and I will run a final year project on it, it will make a lovely honours project, as we can set this up with a gas gun, we can do experimental measurements and we have said that we will do this at no cost to them other than the materials, which is not insignificant, but we will pass the results on to them - and it keep the handle on the company because if the dept. are seen to be able to do this maybe in the long term we will keep the relationship going. Its all about building the relationships - that how I justified doing it. [UR3]

A small number of informants also indicated that this use of the university researchers as consultants or within shorter term focused work, can also have additional side benefits for the sponsoring company with respect to the level of authority in which university research is held. If a company can state that their product or process has been independently tested or developed by academics this may help their product marketing and give their customers more faith in their products.

5.7.2 R&D Management

Analysis of the interview data revealed that in some cases the linkages resulted in unforeseen benefits for the sponsoring companies. In the case of linkages between smaller companies and universities through the TCS scheme the industrial sponsor, along with gaining the academic insights from the research projects, gained valuable experience and expertise in the area of R&D management. The smaller companies that link with universities often have a limited R&D capability and informants reported going to the universities to gain the expertise to develop and understand their technologies, as described by the following industry manager.

Skills in managing research - this is a good point. I'm going to be perfectly honest - that is probably what we need and are not very good at, it is core to us, we should be good at it - that's what we need to be able to do. We are a bit, you know, ad hoc - 'we'll build it and see what happens' - 'well what pressure was it, that's fine, write it up'. Then 2 or 3 weeks later you go back and say 'by the way - what was the wall thickness when it was expanded' and it is 'oh we didn't measure that'. So in that area we are not as good, but that is what the university provides. [IR4]

The input from the university researchers was not limited purely to the application of academic theories to the company's product, but also influenced the way that they developed and produced it. This is adding knowledge and expertise as a by product of linkage that could aid the company in the future.

5.7.3 Staffing and Recruitment

Recruitment was identified by a number of informants as a key benefit to industry of linkage. This was done either directly or indirectly through the sponsorship of both MSc and PhD projects and through the sponsoring of larger scale sponsored research.

As the findings from the survey show, industry often funds PhD students with a view to potentially employing them after they have finished. In addition to this, most university researchers indicated that they were contacted to enquire after potential recruits through their contacts within linkage. Industry respondents reported that this proved to be a highly useful method of recruitment. The trust that built up between partners over the course of the instance of linkage meant that they placed great value

on the recommendations of their university partners as to suitable new members of staff. The industrial sponsor below describes a typical example of this relationship.

...we are funding several projects there, we know the academics involved and you hope you are building up a relationship that will divert the graduates you want towards the company – or at least we will get a truthful response from the academics saying ‘actually you don’t really want to employ them, their science is questionable’ it is just building up the science and the contacts and the communications. [IR6]

One university researcher (below) went so far as to state that recruitment is the key benefit of the university-industry interface and the core role of his interaction with industry, although this emphasis was not as strong in most other researchers.

Lets make this clear - industry gets good quality people from us which is the most important asset. That is really what they get because they need good people to undertake their research. [UR7]

In addition to providing new staff for companies, universities also act in an educational role in developing existing company staff in new processes or knowledge. A number of respondents had experience of providing on site training when researchers visit company sites, or through vocational courses, typically of one week duration, run by the university for company staff which are often included in proposals as an end of project deliverable. These are beneficial to both parties as, although they provide education for company staff, they also act as very effective forums for informal networking, beneficial for both knowledge transfer and maintenance of the relationship.

5.8 Conclusions: Extent, Types and Benefits

This chapter has outlined the main mechanisms of linkage, and the extents and the benefits to both university and industry of the instances of linkages examined during the course of this study. These findings are consistent with those of the survey as outlined in Chapter 4, but the use of the data from the qualitative interviews has allowed depth to be added to the findings of mechanisms and benefits in research linkage in the oil and gas sector. These key findings are described below.

The data gained from the informants on the types and extent of linkage identified the diversity in linkage due to the characteristics of the firm involved in linkage and the

nature of the technology, as discussed in 2.4.3. The large multinational oil firms form the majority of instances of linkage with universities, mainly in the form of long term university based work although some, but not all, university researchers linked to these companies in a consultancy role. This concurs with the findings of Faulkner and Senker, (1995b); Harmon et al (1997) and Corsten (1987) who indicate that the larger, wealthier firms are more likely to fund or have the internal research expertise to take advantage of long term research linkages with universities. The smaller number of instances of linkage with smaller firms identified for this study also support this finding. In addition, those industry informants from smaller firms reported that they were more likely to use consultancy linkages with universities.

Both university and industry informants noted the difficulty that SMEs had in making contacts outside their immediate suppliers and customers. This again echoes the problems of small firms in creating linkages, as identified by Corsten (1987) and further restricted their opportunities to link as informal linkages to university researchers were reported to be important in forming the basis of formal links.

The informants from both university and industry who operated in the field of engineering (a smaller number relative to the geoscience researchers) created links in the context of projects more directly to a marketable technology. Analysis of interviews suggested that longer term research linkages were less likely, relative to geoscience, with the exception to this being the TCS scheme. This reflects the findings of Salter et. al (2000), who indicated that universities provided a high contribution of knowledge to industry relative to other sectors.

Analysis of interviews with both university and industry informants revealed that the widespread use of the JIP system of funding for research projects suggests that knowledge is being shared both between universities and firms and between different companies in the sector. JIPs, although they did not involve a substantial time commitment from sponsors, provided an environment within which trust and respect has built up between university and industry and between the industrial sponsors. This is significant as trust and respect are key factors in any successful linkage (Davenport et al, 1999), suggesting a healthy environment for university-industry

links exists in this sector and again reflecting Salter et al (2002) and Bower and Young (1995) who indicated that university research contributes substantially to the oil and gas sector. Furthermore, the JIP projects did not reflect the literature suggesting that distrust between firms in the sector is high and a potential barrier to joint working (UKOOA, 1993; Crabtree et al, 1997; Bower and Keogh, 1997). Indeed, the indication by informants that JIPs provided a positive environment outside the commercial roles of firms business to breakdown this distrust is encouraging for the sector as a whole.

University researchers who were using the JIP system reported that they could use this mechanism of linkages to maximise their own research potential and capabilities. A smaller number reported that in setting up projects on a flexible basis in terms of the number of sponsors involved, university informants could attract a large number of relatively small contributions from sponsors. In managing the projects in this way the universities were able to generate large scale projects and the industry sponsors could tap into these large projects for a limited outlay. This is a strength of the JIP system for university researchers and one in which both sets of informants reported satisfaction – the universities were able to undertake a larger project and the industry received increased value for money.

The significance of the generation of research ideas and the access to data for research from industry was strongly expressed by university informants. These academics undoubtedly felt that these inputs had a positive effect upon the research they undertook. This was again an encouraging sign for linkage in this sector. Howells et al (1998) suggested that university researchers do not find industry related work interesting or easy to apply to their own research, yet these findings from university informants and the findings from the previous chapter (see 4.5.2), indicate that this sector is unusual in this respect. In addition, the importance of research ideas and data to university researchers also demonstrated that the flow of knowledge between university and industry is a two way flow.

This analysis of the interview data in this chapter also indicated that there were differences between the behaviour and attitudes of university researchers engaged in

this sector. Some informants indicated that they gained satisfaction from working closely with industry, although for others there was a preference to keep academia and industry more separate. These factors shall be further investigated in the next chapter when the relationship between university and industry is examined.

The demands for this sort of applied research, and for consultancy services led to shifts in the aims and workings of some university departments to meet these needs. For example, at Heriot Watt University, the Department of Petroleum Engineering, who align themselves closely to industry, have an industrial advisory board to help maintain research relevance and contact with sponsors. Other universities sprung specialist sections, such as RDR (Rock Deformation Research) Group at Leeds University, EPS (Edinburgh Petroleum Services) at Heriot Watt University, and the Fault Analysis Group, originally at Liverpool University. These organisations are either spin-off organisations or separate sections in the universities and although they still retain connections with the university departments through shared resources and/or staff, they are very much commercial organisations, i.e. conducting short goal orientated consulting projects as a service to industry with less of a purely research focus.

6. The Relationship Between University and Industry

6.1 Introduction

This chapter discusses the relationship between the university and industry researchers in linkage, utilising data obtained from the in-depth qualitative interviews with both university and industry figures. The chapter first focuses upon the methods that university researchers utilise to make contact with potential industry contacts or sponsors. Second, the levels of interaction between the partners in the projects is investigated, including a discussion of the tailoring of research projects by university and industry to meet industry and university needs. Finally, this chapter explores what is transferred in linkage and what individuals from university and industry seek to gain out of linkage. In doing so the chapter highlights the strengths and weaknesses of linkage, the barriers to the transfer of technology across the two research partners, and the role that individuals play in the linkage process.

Chapters 5 and 6 identified a number of mechanisms of linkage and highlighted variation in extent of linkage and, partly as a result of this diversity, interactions between university and industry figures involved in linkage was also found to be varied. The interaction between, for example, the TCS associate and their industrial employer was found to be very close due to the practical ‘hands-on’ nature of these projects and the fact that they worked alongside each other within an industrial setting. Alternatively, the industry contacts of a 3 to 6 year JIP project (which the majority of those interviewed were involved in), working on longer term speculative research entirely based at a university, were much more removed from the work of the university researchers. Consequently, relationships operated at a different and less direct level. Nonetheless, similarities were identified a key example of which was the importance of informal networks in generating linkage. In the following sections the interactions within and outside the linkage mechanisms are explored in depth, based around the themes of ‘making contact with sponsors’, ‘strategies for improving networks’, ‘satisfaction and frustration with interactions’ and ‘the transfer of technology’ between university and industry in research linkages.

6.2 Making contact with sponsors

Analysis of the interview data with revealed a range of routes through which university and industry made contacts with each other (see fig. 6.1). However, informants reported that the most commonly utilised process was through the network of contacts that researchers and sponsors built up through their experiences within the research work.

Fig. 6.1 Methods of making contact to potential sponsors in approximate order of effectiveness

Common Methods of Making Contact with Industry Sponsors
• Through friends and colleagues
• At conferences and through chance meetings
• Through ex-Staff and Students
• Through specific organisations/schemes (e.g. ITF)
• Speculative letters to companies

University informants reported that these networks were very important to them, and often indicated that they were built up over many years involvement with the oil and gas related sector. When asked how these networks were developed, informants indicated that they occurred not only directly as a consequence the linkage work that they had with industry, but also through more informal means such as the people that the researchers may have studied with at university, friends and acquaintances that they made contact with through conferences and so on. This finding strongly echoes the finding in the literature indicating that informal networks are one of the most effective routes to generating linkages (e.g. Faulkner and Senker, 1995b; Davenport et al, 1999). Almost all informants reported that more direct methods such as speculative letters to companies had proven to be far less effective than the use of these informal contacts.

The personal contacts are colossally important, the longest lasting projects have been done through personal contacts...the one thing that doesn't work is the draft letter - Dear [large oil company] do you have any projects? - that doesn't work, you have to go out and discuss it with them, and it has to be at every level, from the junior member of the academic staff through to the those at the top. It is time consuming, very time consuming. [UR9]

As the university researcher above describes, this process is not simple and requires a sustained effort to build up the relationships. University informants suggested that

factors such as the reputation of the department or researcher can help in increasing the chances of success, a suggestion that was reinforced by comments from sponsors, stressing the importance of departmental reputation in their decision to support projects. However, university informants also reported that university reputation alone did not guarantee the creation of lasting contacts and that good interpersonal relationships were an essential ingredient to creating strong formal linkages.

A number of university informants indicated that the difficulties creating and maintaining these contacts had reduced somewhat in recent years due to the mergers and cut backs that have occurred in the sector reducing the number of potential contacts available. As a result many researchers felt that there were potentially few people with which to forge linkages.

...probably the interaction has become easier because there are fewer groups to interact with so you develop better links. You know the oil industry in terms of its research community is relatively small. You don't have to go to many conferences, and you know most of the people at them and know what they are interested in - and then you identify the ones that you think are the way forward and you get feedback from the people that you talk to. [UR14]

This researcher identified conferences as key opportunities for the researchers to increase their network and advertise their work (Harmon et al, 1997; Dickson 1996), however one university researcher reported that many of his linkages...

...have arisen by chance - chance conversation, chance piece of work, meeting on an airport from London, literally that sort of chance contact. [UR3]

This further highlights the importance of the interpersonal element to the building of research linkages. Analysis of data revealed that contacts with ex-students of a researcher now working in industry were an important source of contacts. The ex-students' affiliation to the university or a particular supervisor of theirs may make them disposed to channelling research funding back into their ex-university.

Unsurprisingly, many of the PhD and Masters students at the departments linking with industry go on to work in the sector and as a result there is a direct link from the companies back into university departments. Many university researchers felt that one of the key drivers for a number of the research linkages was a desire to put something back into the system that industry figures had been through. As one university researcher put it

...it is to do with this altruism, they say "look to be perfectly honest with you we have all come through and benefited from the system and we feel we should put something back. Provided the support we give comes up with good research and results and is good for the image of the company that is all we are interested in - and as long as the academics are doing what they are supposed to do then we are perfectly happy with that." [UR8]

It can therefore be very important for individual departments to maintain their links with students that go through their systems. Some informants mentioned utilising schemes ranging from alumni meetings and clubs through to educational courses such as life-long learning programmes to maintain and develop these linkages. These types of incentives have been promoted as routes to developing better university-industry linkages (e.g. Charles and Conway, 2001), but these were not commonly cited by informants as routes that had been used to generating links.

However, most informants stressed that it is often the case that these efforts are not as productive as the informal methods, reflecting the findings of Dickson (1996) and Faulkner and Senker (1995b). The difficulties of making and extending a department or researcher's network of contacts often meant that the sponsors of a significant number of university research projects were not merely contacts built up through organised networking and promotion, but through friends that happen to be working in the same area. The university researcher below demonstrates this when describing the current and future members of a small JIP project.

So it is the old adage of its not what you know, its who you know. Our main supporter has been [oil company A], its not the company, it is one person, basically because he likes what we do...Now the way [oil company B] got involved, well the reason was because their exploration guy, I shared a flat with!! [laughs] In a month or two [oil company C] are coming up here because all their exploration team I was at university with!...One of the other consortium members is a software engineer, and the reason he got involved is because he was a friend of mine. [UR12]

Successful linkages are likely to occur through the build up of trust and mutual respect between partners (Davenport et al, 1999). This will help to ensure good and effective communication between these partners (Senker, 1990) and although this can of course be built up between new partners over a period of time these factors are already in place in the case of working with friends. The good relationship that informants reported they had suggests that even though there were other places that would be as able, if not better, equipped to undertake the research the trust, communication and mutual respect in these relationships resulted in the money going

to those researchers that the industry contacts know, as they have more confidence in them as a researcher. In addition to this, as a result of their friendship with potential sponsors, university researchers also reported that they had a better insight into the sort of features of a research project that particularly appealed to these individual sponsors and confidence that the potential sponsors understood the value of the research. These factors were reported to further increase their chances of obtaining research funding, as described by the university researcher below.

...it is all about contacts, as everything else is, and that means both having good personal relations with companies, and also them knowing what you are about and them being able to appreciate your significance. [UR12]

These insights were undoubtedly a great advantage to those researchers with a large network and it was striking how commonly friends and previous contacts were used as the source of links. This suggests that the 'incestual' nature of inter-company linkages in the oil and gas sector (Crabtree et al; 1997) is mirrored by the university-industry research community. This is further demonstrated by the researcher below in contrasting the benefits of these networks for those already established within them networks against the difficulties facing new researchers moving into the same areas of industrially sponsored research.

... it is increasingly harder for new people to get in. I said it was a lot to do with your mates and so on. So it is a little bit incestuous, but for new people it's tough without a benign uncle in the dept saying "come along you have got good things to offer, I'll help you get into them". [UR11]

So academics, particularly newer researchers with a small or non-existent network, may need assistance from fellow researchers in building up a group of potential research links. This is potentially a role for the Industrial Liaison Officers in universities, but as described in Chapter 4, these were not found to be useful in generating linkages (although this may reflect responses from those already within these networks).

6.3 Strategies and schemes for improving networks

Almost all of the university informants were acutely aware of the importance of making and extending these groups of contacts. As a result, a small number of

informants reported that the informal networking aspect of their roles as university researchers was sometimes made an explicit as part of a formal departmental research strategy document. These documents provided departmental researchers with a range of tactics for networking, ways to get industry contacts involved informally in the department (through open seminars etc), and encouraged 'advertising' the informal expertise and capabilities of a department and offering free advice to potential contacts. The few researchers with access to these documents found them helpful and indicated that enabled them to reflect on their own routes to generating linkages.

These types of tactics were described by the industrially sponsored university researcher below, an author of a strategy document in a industry focused department. Not only did he try to get industry figures (other than his sponsors) involved and interested in the work that he does through inviting them to conferences and meetings, but he also reported actively communicating with the industry figures on a daily basis, offering his expertise to people in a range of roles, to promote his work, increase and maintain his range of contacts, and build the foundations of future linkage.

I am on the phone all the time, every day - chit chat - giving people that you know free advice who are producing - they are not exploring - they are operating a field in the north sea - when they are drilling people approach and ask us stuff. With a new person who doesn't know all about our stuff we will say well can we come into your office, we will bring an hour presentation and we will talk about whatever you want to. If you bring people from a certain asset or group of assets who have the same interests we will bring them in and just talk at that level - we will show you some rocks - some other field - none of it proprietary data. This is free but this is our slant on it - give them reprints but not give them proposals. So the process moves more and more towards a collaboration. [UR10]

These types of departmental strategy were not widespread, yet even with these strategies, contacts are central in building research linkages and require a sustained effort to build and maintain. Again it is interesting to note that this researcher did not use the university's industrial liaison office to assist in this process and reported that he did not find them particularly helpful.

A further acknowledgement of, and response to, the need to extend and maintain networks was the instigation of a research council funded project at an engineering department which had a focus not upon engineering itself, but upon enhancing the

networking processes of engineers. Its purpose was to create a knowledge and information sharing community to enable a whole range of universities to tap into industrial funding. Initiatives such as these and the ITF organisation can assist in creating contacts for those researchers that either have a small network of contacts or are new to the sector, or indeed to those who do not actively network in ways such as researcher UR10 described above.

When discussing the ITF in particular⁴, university researchers held mixed views of the possibilities of gaining research through such an organisation. Some felt that it had many good points in that by making the funding process more formalised through the organisation, the proposals would be based more on merit than on the network of contacts. However, other researchers felt that by removing the direct contact with the industry sponsor and going through the intermediary organisation of the ITF, they would lose the close interaction that can help to shape research projects and enable both the sponsors and researchers to contribute to and understand the goals and uses of the projects. Some had fears that the system may increase the pressure to make research linkages more like ‘applied consultancy and research’, because the broker system could be seen to be commissioning work rather than the university researchers and the sponsors together agreeing a course of work. The other problem with the organisation, from the point of view of some well networked university researchers, was that for those with a good network of existing contacts, and a good level of research funding, it was perceived as adding another level of ‘red tape’ to the research funding system which for them was already working successfully. These potential advantages and disadvantages of the group were effectively summed up by one researcher, who had already submitted proposals to the ITF.

...essentially, potentially it is fairer. One of the problems with everything being based on personal contacts is that people who have very good ideas never get the chance to make their ideas work. One of the problems with ITF is that one company has said don't go to us, go to ITF, so I am a little bit wary of it being simply in a context where the overall level of funding goes down, and everything goes through the ITF and there is no other way...and we may lose

⁴ See 1.2.1 for a fuller explanation of the workings of the ITF

a bit of flexibility...on the other hand it is good because it puts companies together, but the one drawback would be if companies thought that all they had to do was to write a cheque out to ITF each year, people need to be together at the coal face and may get disconnected as they will be working together at too higher level potentially. [UR14]

Conversely, some industry informants reported that they may be attracted to using the ITF for similar reasons. It was thought that ITF could act as a filtering system for university applications for research funding and also be utilised as a method of communicating the ideas for research and problem areas for the companies, particularly as many companies were not, due to issues of priority and time, proactively seeking out research linkages. Some industry informants however, felt that alongside the ITF projects it was important to have projects that they would 'go alone' on. It is perhaps too early to assess effectiveness of ITF at promoting and creating linkages to universities but these are interesting concerns. It was apparent from the significant number of university researchers (particularly those in English universities) that were not fully aware of the role and goals of the organisation. Indeed, in many cases the organisation had to be described to the respondents to remind or inform them of its existence and role. In addition, industry informants reported that the university response to calls for projects had been surprisingly low, and this indicates that it did not have high profile across the full range of university researchers.

6.4 Monitoring research

In the majority of cases, the nature of the longer term university-industry research projects means that the levels of formal interaction (e.g. meetings) between researchers and research sponsors is low. Informants reported that the typical research project is run and managed on a daily basis by the university researchers and often there is little or no input by the industrial sponsors, whose main opportunity to shape and direct the projects are from the (typically) twice yearly formal meetings organised for sponsors. Both university and industry informants indicated that the level of interaction in terms of input related to outcomes and direction of the research is at its greatest at the set up stage of a project, or during the final stages or transition period between 'phases' of an on-going project.

Analysis of interview findings showed that the interaction at this stage of the funding process was greater for two main reasons. First, although informants indicated that more often than not the research ideas and direction were generated by the university staff, these researchers sought to ensure that their research was of interest and potential use to the sponsors. Second, and more importantly for the sponsors, this was the time when they felt that they had the most impact upon where the research was headed. There was an understanding, that, as the managers of the research projects, the university researchers would run the projects in the direction that they felt was the most appropriate. The sponsors did seem to be conscious of the fact that their distance from the projects was a potential problem in terms of its monitoring, as one researcher in a medium sized oil firm pointed out when describing a particular project up for refunding

...it is coming up for second phase - the reason that two of us are going down there to these bi-annual meetings is that it's one of the times where we have a certain amount of influence - "if you want funding next time, we would be happier if you rather than did this, you did this". The meeting before renewal they get sensitive - they listen! [laughs] Once they have got their money for three years I'm not gonna say in the first year they don't listen but they don't do very much when they have listened! [laughs] [IR1]

Thus the sponsors felt that this was their best opportunity to redirect the project and get out of it what they wanted, in the knowledge that their influence would diminish throughout the project as the researchers found their own direction. This again demonstrates the importance of regular informal interactions between university and industry throughout a project, particularly if industry contacts are to gain the most from linkage.

Interestingly, analysis revealed that the university researchers varied in their attitudes towards the level of input into projects from sponsors. Many of the university researchers reported being left to run projects without any direct input from their sponsors and due to the fact that the projects were mostly designed in that way, university researchers were satisfied that the sponsors allowed them to undertake research with minimal guidance. However, some researchers exhibited frustration as well as satisfaction with the level of monitoring. Although this was a greater concern for some rather others, the finding does echo the conflicting responses in the survey

(see 4.5.3) that the researchers were both satisfied and frustrated with the level of monitoring and contact with their sponsors. Typical of this conflict was a comment from the following researcher.

...yes I think it is a bit frustrating [to have so little contact]- there is often silence really...although I would probably not want more direction in these instances - the trouble is we [academics] all tend to be a little stropky about being told what to do! [UR6]

These different perspectives are outlined in figure 6.2. These issues were unsurprisingly less prominent with those interviewed who were working on TCS style projects – as these linkages are structured around academics working in industry.

Fig.6.2. Frustrations and Satisfaction with monitoring levels of industry sponsors

Frustration at a lack of monitoring?	Reason
No	<ul style="list-style-type: none"> • University is running the project and is therefore in charge • Industry is seen as sponsor, rather than ‘collaborator’
Yes	<ul style="list-style-type: none"> • Limited or no feedback on results • Sponsors appear to want to be ‘instructed’ and do not contribute feedback at meetings etc. • Contacts have little time to focus on the research and often disengage from the project • Contacts change jobs

This frustration and satisfaction was exhibited to varying degrees by the individual university informants, and this demonstrated not only their different experiences of linkages, but also their differing attitudes towards and expectations of the interactions in research linkage – themes that have been identified by other researchers (e.g. Rahm, 1994; Butler and Birley, 1998; Klofsten and Jones-Evans, 2000) and will be explored further in the next chapter. The characteristics of the university researchers’ satisfaction and frustration are presented below.

6.5 Satisfaction with research monitoring

The university informants reported satisfaction with low levels of contact for two main reasons. Firstly, because they felt that university run projects should be

managed by those in the university and secondly because they felt that any additional input from the sponsors would hamper their progress with the project.

The university researchers running the projects were aware of the need to allow the sponsors to direct and steer their research, indeed in some cases (see 5.5.2) the ideas for the projects came from the industrial sources and it was the industrial partners problems that sparked the research project. These interactions occurred most effectively when the project was being set up and from then on the projects were, in the main, steered and controlled by the university. This was a necessity as much as anything else, as even though the industry contacts knew how they were likely to utilise the information, were likely to be technically adept and often had some form of research experience, the research had to be undertaken in a coherent and progressive manner. Sponsors were not directly involved in the work on a daily basis and therefore did not contribute effectively to regular steering of the projects. The nature of the sponsoring most of the projects, that is through the JIP system, meant that it was highly unlikely that any one particular company would be able to greatly affect the direction of the project, as they needed to reach consensus amongst the sponsors. A university geophysicist describes this situation saying that

I'm of the opinion that, it's a two edge thing, I can't be steered by a consortium that has five or six interests in it - you can't listen to them all - and we are quite happy, and have faith in our own judgement that we can choose the most profitable line of research. Having said that it is always useful to have constructive input on about how the package can be improved and delivered and I have had that from some sponsors, which is good. [UR12]

In some cases, the course of the research often shifted or hit problems and university researchers took note of the needs and concerns of their sponsors through the on-going dialogue with industry. As a university petroleum engineer describes, typically,

I would say that we steer it and we get to [steering group] meetings prepared if we want to change things. We are organised and suggest a direction, rather than say 'which way do you want to go?' Of course we are doing it full time, so we are in a very strong position, having said that if they [the sponsors] hate it, they will tell us and say no you can't do that. But the working relationship is generally very good - rarely a problem. [UR11]

Indeed, the two quotes above suggest the working relationship between the sponsors and the university researchers was in general good and there was an understanding of

the nature of this form of linkage from both sides. A large number of the university researchers indicated that there was little need for the industry sponsors to get involved with the running of the research and reported they would rather that they were left alone to run the project by themselves.

it's a personal view - I don't find it particularly frustrating, I take a more hands off approach - if they are giving us money to do work and it is interesting how they use it is up to them, the worry is that if they don't have the time to get on top of the work, the chances are they are not going to invest further - that is my worry. [UR11]

However, not all university researchers were satisfied with the levels of monitoring, and the reasons for this dissatisfaction and frustration are described below.

6.6 Frustration with research monitoring

For university researchers, frustration with a lack of monitoring and contact often went hand in hand with their satisfaction of being left to their own devices.

Frustrations occurred due to the nature of the interface, that is the lack of regular contact between researchers and sponsors, and the research project's low priority in the sponsoring company. These frustrations, more specifically, were related to a lack of feedback from the sponsors in relation to the running of the project, a common tendency for the sponsors to become disengaged with the projects, problems when contacts change 'job' and therefore a new contact in the company had to be made, and finally the view that the monitoring of these projects was as much of a hobby to the sponsors as it was a part of their job (which did, however have benefits as well as disadvantages – described below). These factors are discussed in turn below.

6.6.1 A lack of feedback

The formal meetings for the steering committees of particular research projects offered the opportunity for the sponsors to give feedback upon the progress of the work and on the suggested future course of the research. In general, the university researchers suggested that the level of feedback from these sponsors could be greater. A number of the university informants indicated that often there appears to be a lack of response from the sponsors' representatives to the presentations given.

This suggests that in a number of cases, providing the research followed an agreed course, the sponsors tended to want to be informed of the research rather than directly input to it themselves. Although university researchers reported wanting to run the projects as they saw fit, this did not prevent the university researchers expressing a certain amount of frustration in this lack of feedback. Despite the lack of formal direct contact, aside from the formal meetings and presentations, university researchers clearly expected the sponsors to use these occasions to provide useful input and feedback. Yet again this highlights the need for informal interactions around project work.

This expectation of involvement was exhibited by a geophysical researcher when discussing the first meeting of a new consortium of sponsors. The researcher expected to encounter debate and potential problems during this set up phase. He was aware that the different sponsors had potentially different uses for the project, and was particularly concerned as the project had arisen from an industry problem

...each of them had different needs and requirements - none of which we knew throughout the project - a consortium is very unresponsive in a meeting and what we didn't realise is that they tend to prefer to be driven instead of this asking questions malarkey. In response to 'what do you think about this?', it is amazing the lack of response you get, even from people from different levels - they are not being secretive - they just prefer to sit back and be instructed, and be educated about things. [UR10]

This experience was not untypical of university researchers who were surprised that sponsors were not more enthusiastic to get involved. Indeed, university researchers often found that their relationship with their sponsors during these meetings, was more educational rather than 'collaborative' and, as the following informant's comments show, felt that this impacted upon their ability to meet the sponsors needs.

[It is] slightly frustrating you know, you go down to these companies, particularly if you get students, and you don't get any questions!!! It bothers me a bit, I don't feel that we engage completely, erm you know - because we are not being driven by commercial goals - its a totally different mindset - they are happy to disengage from that because many of them have been PhD students they have gone through the academic system, so they simply sit back and enjoy themselves I think. [UR8]

The researcher above not only exhibited a frustration at the lack of feedback but also acknowledged the differences between the sponsors and the university researchers. He highlighted what he called the different 'mindset' of some industry sponsors, and

indeed this was not to be unexpected given the nature of their relationship. In these cases the university research was often peripheral to the sponsors normal day-to-day work, and as a result they were disengaged from the projects. University informants suggested that the majority of sponsors will have been through the academic system and will appreciate and enjoyed the work of the academics, but in many cases were content to view and understand the research without integrating it into their normal work. Indeed, in a large number of the university informants there was a feeling that, although they felt that the sponsors appreciated and understood their work, the limited time that they were able to spend on the projects with university meant that they were speculative additions to, as opposed to integral parts of, their job remit. As a result there was less pressure to closely scrutinise the projects on a regular basis, as indicated by the following university informant.

I have to say that my experience of that is that generally you don't get a lot of feedback actually - you find yourself going along and you give a presentation to a sponsor company and they enjoy it and they say 'we really did enjoy that so much more interesting that what we usually have to listen to' but it is fun for them - it is not really proper work - it's "oh well this is interesting, this is something that we are funding". [UR8]

These findings show that, in most cases, the sponsors fund projects not because they are going to produce something that will help the company in the short term but because of the small possibility that they may develop something of great value in the future. The speculative nature of this work means is perhaps not surprising that the sponsors do not view these projects as a high priority for their attention.

6.6.2 Sponsors disengage from projects

Although the low priority within which the projects are held by the industry sponsors (relative to their day-to-day work) was understood and accepted in the main by the university researchers, it was a subject of some concern and frustration, particularly with some contacts/sponsors in the larger JIP projects. It was common within these projects to find that contacts becoming disengaged from the projects. This was not only exhibited through a lack of feedback at meetings and so on but university informants often indicated that it was also common for representatives to miss a number of meetings and to lose track of the project. This in itself was not necessarily

damaging to the project on either part. The sponsoring company still received the deliverables and if, for example, data was required from sponsoring companies for the research to be undertaken it was highly unlikely that to come from all the members of the JIP. Those that became disengaged were unlikely to be the ones providing the data and therefore the project continued to progress. Yet the lack of an active input into projects may mean that these contacts were not gaining the maximum out of linkage, particularly as they were not fully engaged with the research through informal interactions with researchers. This general impression of the varying interest of the industry sponsors was described by a university researcher below

I guess that my experience is that there has been a large enough fraction of the sponsors who have been interested in it to make it worthwhile - I don't frankly expect that in a 7-8 company consortia that they will all to have the same level of interest, so that is just the way of things. [UR11]

The two quotes below exemplify the problems of this lack of contact time on projects from each perspective. First, a university researcher described his concerns over the level of contact and interaction between the partners in the research and the frustration and disappointment that a lack of attendance or total loss of interest can caused.

You see people in project meetings and I can have a good rapport with them and it can be quite positive. It is unusual for someone to be really critical of work, the problem is the people that don't attend and don't show interest in the work. You have gone to a lot of effort to have a programme that is technically sound etc etc, got the contract signed and then either that person is too busy or no one seems to be interested - and this is disappointing. We want to know - we want feedback - and secondly it is also concerning 'cos you know that company is going to drop out [and not fund next time], that is frustrating. [UR14]

From the other perspective, the industrialist below (now semi-retired and working at a university) described how of external university work was necessarily lower priority than the internal projects and how the resulting difficulties in staying closely involved with the work was frustrating.

...so you set up a project, you get it all going...and then you then give way because you have other commitments and can't devote time to one particular project. Because it is not on your immediate doorstep it doesn't take up and have the immediate high profile that it would if it was internal. Therefore to some extent you lose the thread and the grumbles that come about losing content - they are as much the responsibility of the industry supervisor as the university researcher, but there is not much that you can do about it. If it has the level of priority that

says instead of doing it in-house we'll send it out to be done it immediately gives it a different scale - it doesn't diminish its importance, what it means that you have prioritised because it is less immediate. So you get six months down the road and you know that you have lost touch [UR13]

Despite the general acceptance of the low priority within which projects may be held by industry contacts, it did create long term concerns for the university researchers. As well as providing feedback, the meetings between sponsors and researchers were opportunities to build up long term working relationships. University informants indicated that a key benefit for the university of this was that a good relationship with a current sponsor makes it much easier for them to gain further funding in both new projects and in subsequent phases of work, echoing Davenport et al (1999) and Faulkner and Senker (1995b). If the sponsor disengaged from the project, future funding may be lost and as a result the scope of future work of the researcher was potentially diminished. This is expressed by the following university researcher

...that's the problem, because they are the companies that will drop off [from sponsoring] next time. There is no doubt that there is a correlation between interest and attendance. If there is a person in the company that you know and you have a good record with them, they come once or twice a year and they are interested - it works even if they are not getting something out of it, even if they are not using the code, they haven't given us data - as long as there is someone there that you know who is kept happy. If you have companies that do not attend meetings, you can guess what will happen - someone says well we are given them £15k and someone umms and ahhs and then they manage to find the contact and give them the CD-ROM or the booklet and no one reads it and they say what is this worth to us? We have got photocopies of a few papers that we could get anyway - a CD-ROM that no one has ever looked at a website no one has seen ... you know.... [UR14]

The university informants indicated that the potential consequences for the oil company sponsors of not engaging with the research were twofold. First, the potential benefits may not have been maximised, and second, more importantly, they ran the risk of missing the significant advances that this kind of research offered when they happened. This situation was described by the university researcher below, when talking about a 'latecomer' to a JIP.

The interesting thing is that it wasn't necessarily the members of the original JIP that took it on. What they did do was produce a creative environment that created an interest and different companies picked it up. This is why the companies should take a longer term view - sponsorship doesn't just make things happen - but to justify it to managers they have to say that it will do something. What happened was very interesting, many of the companies who had originally sponsored it became very blasé about it. We presented at a meeting with a company that we have never used on the project before and they said "this is marvellous - we are missing the boat, these companies have been funding it and have done nothing - we will

get the software and start using it” So that has been somewhat amusing - it worked but it wasn't the smooth way that you would think. [UR14]

It is interesting to note that in this case the new sponsor saw the potential development of the research. As a new sponsor, an examination and assessment of what the outcomes of the project will have been undertaken. This highlights two important features of the university-industry research relationship. First, as discussed above 6.4, the level of dialogue and pressure to tailor research projects was strongest and had most effect at the beginning of a project, when researchers tried to gain further funding for a subsequent stage of the work, or when new companies join consortia. Second, that it was difficult to create and maintain effective and consistent transfer of knowledge from these projects to industry. This will be investigated further in the final section of this chapter.

As a result of the restructuring and downscaling of the industry in recent years, informants reported that many oil industry employees changed jobs and therefore left the consortium to be replaced by new company representatives. It was regularly remarked by the university respondents that in most JIPs there have been changes in the contact personnel. This was found to be a problem, not only because of the fact that the new contacts were not interested in the particular project, but also because additional time and effort needed to be expended building up new relationships. Several respondents pointed out that at meetings a large amount of time had been ‘wasted’ going over old ground to get the new contacts up to speed on the projects as a whole, rather than tackling the immediate issues relevant to the project.

It worries us that we spend a lot of time and effort building up the relationship with the people and then suddenly you ring them up and they have gone and they don't tell you - that is very difficult. [UR6]

These problems were also identified by Dodgson (1993) and Webster (1994) who found that university researchers experienced difficulties in maintaining effective linkage work when industry contacts changed.

6.6.3 Sponsorship as a hobby

University respondents reported that much of the frustration described above by the university researchers in relation to the level of informal and formal contact and feedback provided by industry representatives, had to do with the amount of time that industry sponsors were able to devote to their linkage activity. Some university informants indicated that in previous years oil companies often had members of staff who were solely devoted to managing university or other external research, but that this was now extremely rare. As a consequence, the industry staff who were linking with university rarely had the time to fully devote themselves to the research projects they were involved in.

There is a frustration with a lack of time these guys have, not with the way they use the technology, but with getting samples, getting data you need to do the work, this is not a top priority for these guys - in a lot of cases they are doing stuff in their spare time - they are not even necessarily allowed to write hours against this project. So it is a background activity they are doing for their own interests or career progression or whatever. So that can be quite frustrating. [UR11]

As the university researcher above described, this lack of available time made it difficult for the university researchers to gain access to information required from the industry to enable the projects to run. This aspect of the transfer of knowledge and technology with projects will be investigated further in 6.7. However, this highlights the need for at least a few of the industry contacts to be interested and engaged in the work for the linkage to develop fully. Indeed, it was suggested by a number of the university researchers that the best contacts for them to have in industry were those who treated their external research in universities as a hobby as well as a part of their work remit.

University informants reported that as external contributors to projects, generally offering information to the projects on infrequent occasions, industry sponsors easily became detached from the linkage work. The majority of these contacts had been through the academic system and many had undertaken some form of post-graduate study and therefore had an understanding of the process and workings of academia. The efforts required of those that wished to maintain this interest in research led university informants to report that these industrial contacts provided the best type of

industry contact. They were much more willing to go out of their way to access company information or data and to spend time ensuring that it was in a useable form for the project. These types of contact were also be much more likely to attend meetings and maintain a close working contact with the project.

The value of maintaining this kind of contact throughout the course of their career was highlighted by many university researchers and several informants spoke of the good relationships they had with a particular industry individual. These contacts often continued sponsoring work with particular researchers or departments despite many job changes and promotions. One researcher gave a typical example of this form of long term relationship when describing one particular sponsor.

He is now higher up in the company [than when he first sponsored us], but he is still our 'sugar daddy' basically because he likes what we do. He is very keen on the subject area of 'basement' and is known for publishing on it...I know he finds it hard trying to juggle all these different jobs but you could say we are his hobby! (laughs) [UR8]

The distinction between these 'hobbyists' and the industry contacts who devoted little or no extra time to university-industry research linkages appears to mirror the differences highlighted in 5.6 and 6.5 and in the literature (e.g. Rahm, 1994), of different perspectives on linkage by different university researchers. This again highlights the importance of individuals and the relationship between them on the linkage process.

6.7 Transferring technology

The final section of this chapter discusses informants' descriptions of what was transferred in linkage and analyses the problems in transferring linkage both from university to industry and vice versa. This also further highlights differences in individual researchers through discussing the different reports of how university researchers sought to ensure (or not) that their research was absorbed into industry.

The technology transfer within these research projects occurred in both directions, from the universities to industry and vice versa. This emphasises the discussion in 2.2, that linkage should not be viewed as a linear process but as a two way interaction. The university provided information in the form of new knowledge,

theories, papers and software, and in turn industry feedback results, practical knowledge, ideas, and data (as outlined in 5.5.2, and 5.5.3). From this perspective, a good linkage was one within which there was an effective flow of information between both sponsors and the researchers through both formal and informal methods. This was always facilitated by good interpersonal relationships between the sponsors and the researchers, as outlined by Dodgson (1993).

However, academics concerned about the level of transfer of their work, reported that the good relationships that existed in the majority of linkages did not always mean that the flow of information between the two parties was as high as it could be. Fundamentally, as Senker (1990) suggests, to maximise the transfer of technology, both parties must invest time on the research work. Without this, it will always be difficult to do anything other than pass on the knowledge. This was explicitly acknowledged by some informants, as the following quote from a university researcher highlights.

It comes back to the point I made earlier - technology transfer is a very difficult issue - it does take time and therefore money on the part of both parties and I don't think it is something that we [as partners in research linkage] have worked through very well. That can't be to anybody's benefit. [UR11]

Both university and industry informants highlighted that the oil company representatives did not have a great deal of time to devote to these projects. They were often involved in university research as an extra, not an integral part of their jobs, as a result, only those with a keen interest in the projects, or whose work the project had a direct influence upon found the time to read the research output.

The reality is that most people don't read them [the reports], so I find that slightly perturbing. We are spending a lot of time writing those reports but it is not clear who is reading them. And there is a reality that only a fraction of the reports are relevant to any one company and second there is a lot of detail in there that they don't want and can't handle. So however good the work is that we do, it takes time and money for people inside the company to take on the fraction of the work that is relevant to their companies and then translate into their workplace. That is a real issue, I know in a lot of cases they are simply not doing it - so why are you funding us if you are not actually taking it on board? [UR11]

The researcher above highlighted three problems related to this lack of uptake of information and ideas. Although this particular researcher was more concerned about

the issue of transfer of the research output to industry than some university researchers, his concerns were not atypical.

Firstly, he highlighted one of the potential problems of the JIP system, that of a large number of sponsors potentially pulling the research in different directions, and as a result, the output being of less interest to some others. Although it is highly unlikely that the output will be of no interest to any particular sponsor, it was not uncommon for sample data to be provided by one or two sponsors only in a large consortium, making the work of greater interest to them. In addition the projects were wide ranging in their scope and sponsors joined the consortium because of an interest in different aspects of the research - again, as a result not all of the sponsors were as interested in each paper. Secondly, the technical content was sometimes a problem, as there was always likely to be a range of different expectations from the industry sponsors of the type of output that required - some wanted academic style papers, others more practical, less technical documents. Thirdly, some sponsors did not have or make enough time either to read and understand the output of the research projects, or to apply the new knowledge to the workplace.

Some university researchers reported that the most effective way to enable the new knowledge to be passed on to the sponsors was during visits to the companies. The opportunity for the academics to pass on their knowledge to industry scientists through informal discussion with industry staff about their work did not occur regularly within projects, indeed it was reported that it was extremely difficult for university researchers to visit all the members of a consortium on a regular basis due to their own time commitments. Valuable instances were reported by academics of their input changing the way that the industrial researchers viewed their problems through short discussions and advice in the workplace. It is exactly this form of informal advice, expertise and assessment that one of the researchers interviewed was individually sponsored by a single major oil company to undertake. His remit was simply to apply his academic knowledge, through his own particular perspective, to the current work of the industry scientists during short visits to the company on a regular basis. This example illustrates a way of getting the university knowledge into

the companies more effectively, but through more informal means, and in this case the end result appears to have been successful on both sides of the collaboration. This concurs with Faulkner and Senker (1995b), who suggest that one of the key university benefits to industry was practical help and assistance.

However, other university researchers suggested that in response to the difficulty industry scientists have in staying fully engaged in external research projects, they have sought to influence and shift the outputs of university research towards more commercial goals. This is shown by the rise in commercial wings of academic departments at for example, Leeds and Heriot Watt universities, who undertake work more along the lines of bigger consultancy projects rather than the more speculative research work of the sponsored university research projects. Some university researchers within sponsored research projects indicated the problem of being pushed in this more commercial direction. The researcher below described the pressures from sponsors to produce a more commercial product, in this case a piece of software.

I don't think they [the industry staff] have the time essentially to go to conferences and come and see us and so on. I think what they feel is that they want the universities to become more like industry research centres and to push the development and to push code that is closer to implementation. [UR14]

The university researcher above reported that sponsors were understandably seeking something that can, if successful, be easily implemented into their systems. The researcher, however, saw his role as one of undertaking research and developing new techniques and theories and not being part of a technological development team. Alternatively, other researchers suggested that further steps could be taken to try and improve the way that the university and industry work together through the creation of more extended linkages around some projects which may have a higher probability of success.

So I wonder whether we do need to move to a model agreed between industry and us of spending a greater fraction of our time and their time, and hence a greater fraction of the budget of the projects, on technology transfer. So if I was them what I would do is to have a budget of, rather than £25k per year and what they have internally, is to try to make an additional bilateral link so that at the end or during the projects to work more closely with the people. [UR11]

This view is from one of a number of university researchers who felt strongly that the access to, and utilisation of the work that they undertook, should be increased by their sponsors. However, alongside these transfer orientated researchers, there were a number of academics who are quite content to undertake their research and do not necessarily see themselves as a provider for the oil industry, rather someone who merely undertakes research which happens to be paid for by companies, rather than research councils.

sometimes they will say they are a good group and fund them and they don't really monitor how effectively they have used the information. That is a shame really that they spend the money and don't get any value from it - to be honest if they keep funding me and they are not using the info well that's their fault - however clearly it is in my interests to make it as readily available as possible.[UR14]

As suggested above, a number of researchers reported that one of the most effective methods of increasing technology transfer was through informal situations where a dialogue could be built up between people and the individual problems and needs of people could be addressed. This occurred most frequently through meetings outside of steering groups, for example 'in the bar afterwards', and through queries and requests made by telephone and through visits to company sites. These mechanisms all allowed for flexibility in discussion and for unforeseen issues and useful information to arise and be discussed. Residential field trips and training modules at the end of a period of research funding were found by a number of university informants to be an effective way of facilitating this form of interaction. Typically, these lasted a week and involved industry representatives being taken to a geologically relevant location where they can, for example, view analogues of the rock structures that they were investigating and gain instruction in new techniques and findings.

In my field the best way to effect technology transfer is in running field trips - usually in south-east France, where they might spend a week visiting rocks. That is expensive, but in terms of getting the ideas across, it is really effective. [UR12]

University researchers were particularly concerned to transfer technology effectively for two reasons. Firstly, to keep engaged with industry sponsors to maintain the funding for projects in the future. Second, because they were personally committed to the work that they were doing and wanted to see it used.

6.7.1 Problems transferring technology from university to industry

Aside from the overriding problems of the industry sponsors having limited time to fully investigate the research outputs, academics also noted more specific problems related to the nature of the transfer of knowledge to industry from university. The ‘traditional’ academic outputs of research papers, theses, and in particular in the case of commercial research, reports were produced as part of the research linkage investigated in this study. Many university informants reported taking steps to try and improve the transfer of knowledge by changing the nature and form of these deliverables.

Fig. 6.3. Transferring technology from university to industry.

Type of Technology Transferred: University to Industry	Form of Transfer
Theories and interpretations	Reports, papers, theses
Analysis Tools	Software
Informal Advice and Training	On-site visits, field trips, placements
Analytical Services / Problem solving	Short-term consulting projects

The most widely utilised change by academics in this respect was the use of the internet to act as a medium for the dissemination of their research output.

Disseminating research through the internet had the advantage of getting beyond the desk of the sponsoring institution’s representative directly to those who needed it.

This also benefited researchers as the increased audience increased the profile of their research. As the university researcher below describes

the website is great because it means that we can deliver stuff quickly, we can bypass the contact person if they are choosing to not disseminate the information for their own reasons - which has happened in the past where you give somebody a printed report and they sit on it and they will dish out tit bits of information to bolster their position, it helps them but when it comes round to funding again it doesn’t help us. [UR9]

The nature of the project websites varied and in many cases the universities were still developing their usage. However, they were often much more than simple repositories of academic papers in electronic form. Informants reported that they had been developed to include shorter papers and slides from presentations and notes on the administration of the projects. The websites were also used to provide downloads

of software developed within the project and also to provide support documents such as instruction manuals to assist industry staff in utilising software or applying new models. Most of these websites had password access to sponsoring companies only, maintaining the levels of confidentiality within the project.

It was felt by the academic researchers that the development of the websites has achieved an increase in the flow of information from the universities. Certainly, those that had kept track of the number of 'hits' to their sites reported satisfaction with the results. In addition to the development of websites as a method of transfer, academics took steps to ensure that the outcomes of their work, in the form of papers and reports and so on were more accessible to their sponsors by, in some cases, moving away from traditional academic papers to documents more easily read and understood by the non-academic. The production of software or techniques that could be utilised or incorporated into company systems are other ways of making the outcomes of research more transferable to industry.

Underpinning all of these enhanced methods of transfer was not simply a need to place the technology in a form that is less 'academic' and therefore easier for industry sponsors to understand. Some university respondents indicated a need to increase the level of transfer of not only the deliverables but the associated tacit knowledge between partners. Informants identified that software is of no use if users cannot understand its purpose or utilise it correctly, similarly new ideas in the form of papers and theses are much more likely to be transferred to industry if the researcher can go into the company and see how her/his new knowledge will affect working practices or current techniques.

6.7.2 Problems transferring knowledge from industry to university

The problems of technology transfer were not limited to the flow of information from the university to industry, but also occurred in the other direction. One of the key benefits to the university of linking with industry was in gaining access to accurate real data to utilise in their research. This data was reported to be of much higher

quality than that which they had access to outside their industrial contacts, as a result, greatly aided the development of the researchers' work.

Fig. 6.4. Transferring technology from industry to university.

Type of Technology Transferred: Industry to University	Form of Transfer
New problems	Dialogue at conferences, informal chats, appeals to universities etc.
Data	Direct transfer from companies within projects
Results / feedback on theories & tools	Discussion at steering meetings etc.

Sponsoring companies could gain benefits through providing the university scientists with both useful and accurate data, particularly if the project was based around a problem that the industry was trying to address with one of their sites. However, one of the most common problems pointed out by the university researchers was that of gaining access to this data. In many cases where the data had been offered to the project, the university had problems in gaining access to it, or indeed getting it in a form that could be useful to them.

Three examples of this, which exhibited the typical problems associated with the transfer of data from industry to university are described by university researchers below.

...things like getting data out of them is a real nightmare, the project is ranged all over the Atlantic margin, it requires us to get data from all over the place, that is a real pain in the arse. Actually getting someone at the company to focus long enough to go and get the data that you want and go and deliver it to you...there is a communication problem in one sense. [UR6]

This first quote again reflected the lack of time that the industry contacts had to apply to these projects. In this case, the data that the project requires was not readily available as it was spread across a range of sites. This research work at the university, not atypically, was working into applying a new method of investigation of phenomena and as a result needed data from a wide range of sources rather than looking closely at one particular area. Subsequently, the industry contact spent additional time and effort, potentially outside their job remit, collating this data and getting it to the university research project.

Usually we go through a very long process of agreeing an agreement, not that there is anything very controversial about it. It is just that every iteration takes months and then it is handed on to someone else who is supposed to give us the data, and then a month more goes past and then when it does arrive it is in the wrong format or it is on a media that we cant read and then we send it back and more months - it is dreadful actually. [UR6]

This second quote highlighted not only the potential problems of obtaining agreements to share potentially confidential data amongst members of a consortium⁵ - sometimes involving legal agreements - but also the problem of the time delays caused by both in reaching the agreements, and in getting the data to the university projects in a correct or useable form.

The main problem is getting the companies to give you appropriate data, they always appear very keen to give you data, but when it comes to the crunch it is often not what you really want or they have unrealistic expectations of what they think you can do with it. [UR14]

This third researcher highlighted the problem of receiving the appropriate data, but also raised the issue of the expectations of the providers of the data. At times, university informants suggested that their sponsors expected too much from their research work in terms of directly applicable results.

The informal feedback, on for example potential areas for research, that the industry provided to the research projects was of great value to the researchers in planning future directions for research, gaining new ideas and refining current work. This of course not only helped to move the work forward, but also ensured the researchers ongoing employment as many were funded solely by external research money. Researchers often gained this valuable informal knowledge that helped them to develop their work during informal visits to companies.

All these examples of the problems of transferring knowledge to university from industry, and vice versa highlighted the importance of communication in linkage. Good communication and understanding enhanced the transfer process. However, as

⁵ The problems of data confidentiality amongst consortium members in relation to geological data were solved by the supplier company changing the data so as to make it almost impossible to isolate the location, but retaining the features of the geological phenomena. This enabled the company to maintain proprietary data from particular sites, although in the main, work on university research projects was of a generic nature, and therefore is unlikely to be commercially damaging if allowed in the public domain.

described above, the time that the industry contacts had was extremely limited and as a result restrictions were placed upon the effectiveness of knowledge flow in both directions. This is summed up by the following quote from a university researcher.

yes, there is only one way that you get technology transfer is if you devote time to it - it does not work by a magic process. [UR14]

6.8 Conclusions: The relationship between university and industry

This chapter has closely examined the research relationship between university and industry through data collected from in depth interviews with university and industry informants. This discussion of the research findings has highlighted two key themes evident in the practice of university-industry linkages in the oil and gas sector – the importance of informal interactions in the generation of linkages and transfer of knowledge in university-industry linkages, and the differences in attitudes and behaviour of university researchers and industry contacts in linkage. These two themes are interrelated, as the attitudes of individuals towards linkages are likely to affect the nature and extent of informal linkages they are willing to engage in.

The data collected from the informants demonstrated the huge importance of personal contacts in the generation of research linkages in this sector. This echoes not only findings from both the literature on university-industry links (e.g. Davenport et al, 1999), but also the findings from the industry related literature indicating that inter-firm links can be very ‘incestual’ (e.g. Crabtree et al, 1997). This situation has both positive and negative implications. The trust and mutual respect essential for effective linkages is present between partners, increasing the chance of success and the informal flow of knowledge between university and industry. However, those researchers without networks found it increasingly difficult to gain funding. This applies particularly to new or young university researchers (especially those within a department that has a lower reputation for oil and gas research), an acknowledged problem by some respondents. In addition, industrial figures in small firms also found their linkage opportunities restricted by this situation.

Informal interactions, both within and outside projects, were also identified as a key routes to the exchange of knowledge and information between partners in linkage. This included the findings from research, but also new data from industry, feedback on progress and new ideas for research. These are key benefits from the oil and gas industry to university research that are not identified in other sectors (e.g. Charles and Conway, 2001; Howells et al, 1998). In addition, informants identified that the transfer of tacit knowledge that is required to utilise and understand new knowledge (Polyani, 1967; Vincenti, 1991) was also transferred through these informal interactions.

This findings outlined in this chapter also highlighted that the presence of a range of different attitudes and practices of linkage by university researchers and by the contacts in industry. This echoes findings from other research into the practices of university researchers involved in linkage (e.g. Rahm, 1994; Butler and Birley, 1999; Klofsten and Jones Evans, 2001; Santoro and Chakrobarti, 2002). Interviews with the university informants indicated that some prefer more input and monitoring from industry than others, reinforcing the differences noted in the survey results (Chapter 4) between those with higher and lower linkage scores. These differences led some researchers to look for much closer links with industry and to ensure that project deliverables were transferred effectively. Others looked to increase the flow of information (through formal and informal means) back to universities to facilitate the generation of new research ideas. However, for some respondents the limited input from industry was what they desired to enable them to conduct the research as they saw fit. In spite of these differences in perspectives, all researchers felt that the research that they undertook was both interesting and stimulating, in contrast to findings from surveys of university-industry linkages across all sectors in the UK (Howells et al, 1997).

The attitudes and behaviour of industry sponsors were also found to vary in a similar way to the university researchers. The research findings identified a distinction between those that could be labelled as 'sponsors' – those who funded research, but had a low level of informal interaction with projects outside meetings, and

'hobbyists' – those who were particularly interested in university research and treated their engagement with it as a hobby. As a result the 'hobbyists' were more likely to interact informally with university and make extra efforts to assist research projects through sourcing data, or give feedback on research to academics. The university researchers that were more keen to link with industry were particularly enthusiastic to work with these types of contact.

Those industry contacts with lower interest in linkage - the 'sponsors' - gave less in feedback to the research projects. This lead academics to believe that they were wasting their time in tailoring work to meet industry needs. These feelings were further compounded by changes in industry contacts to projects. University informants reported that those that replaced contacts half way through projects contributed very little, and failed to attend meetings. This has implications for the good relationship that in general was reported between contacts and academics and creates the possibility that industry may not be able to get as much out of the universities as is could. Indeed, both industry and university informants indicated that industry inputs little in terms of direction to projects after the project has been initially instigated.

Senker (1990), notes the importance of both partners 'making an effort' in successful linkage and the fall off in interest by some industry contacts allied to the lack of time available for contacts to devote to this research raises some concerns. The downscaling in the industry, mergers of major companies and subsequent reduction in number of contacts and their time for university research compound these issues. Many informants reported that contacts, in particular the 'hobbyists' often funded university research as an activity outside their work remit. If these industrial pressures on industry contacts continue to restrict time for links to universities over the longer term, there is a chance that the immediate importance of linkage to these contacts will be further reduced. This may subsequently reduce the mutual respect currently displayed between university and industry researchers, a key aspect in successful linkages (Dickson, 1996) and lead to missed opportunities in the transfer of university knowledge to industry.

The findings presented in this chapter indicate that academics and industrialists who are keen to work with each other are more likely to engage in informal linkages. The importance of informal linkages in exchanging knowledge and generating linkage opportunities is therefore strongly dependent upon individuals. Unfortunately little research has focused on the exploring the reasons for different behaviour in those involved in linkage (see 2.5) yet, given the importance to this of accessing the benefits from linkage activity, this is a key gap in the understanding of university-industry linkages. The research undertaken in this thesis does examine the reasons for different attitudes and behaviour and these are explored in the next chapter.

7. The Collaborative Outlook

7.1 Introduction

Over the course of this research into university-industry linkages in the oil and gas sector a number of key themes have been identified. Chapter 6 in particular has highlighted that university-industry linkages are relationships between university and industry researchers, within which informal interactions are crucial to the exchange of information and development of research ideas. Differences in attitudes and behaviour of those involved in linkage were identified and the extent to which these differences corresponded to the expectations of linkage, benefits received, and levels of interaction between the university and industry researchers were highlighted.

To understand these relationships, and what makes them operate effectively, it is therefore important to understand the differences in attitude and behaviour of those involved in linkage activity. This chapter develops such an understanding through exploration of the *collaborative behaviour* of the university researchers involved in linkage. The term *collaborative behaviour* is used to refer to the extent university researchers work and seek to work with industry in the oil and gas sector. The exploration of collaborative behaviour in this study builds on previous research reviewed in Chapter 2 that has sought to classify university researchers by their levels of linkage activity (e.g. Rahm, 1994; Santoro and Chakroabarti, 2002 and Butler and Birley, 1998) but extends this to examine why researchers have different levels of *collaborative behaviour*.

This chapter draws together the key themes identified in this thesis and findings from the literature to develop a framework – ‘The Collaborative Outlook’. This both identifies and explains the behaviour of university researchers involved in linkage activity.

The chapter begins by describing the development of framework, undertaken through the iterative analysis of the university researcher interview data in conjunction with review of the literature (see 2.5.2). The framework is then described in depth. The

findings from the data are then used to develop three ‘exemplars’ of university researchers with high, medium or low ‘collaborative outlooks’. These demonstrate how the ‘collaborative outlook’ framework can be used to both classify and explain the behaviour of university researchers involved in linkages. Three case studies of individual researchers interviewed in this thesis are then presented and discussed. Comments on the applicability this framework to the industry researchers are discussed in the conclusion of this chapter.

7.2 Development of the Collaborative Outlook Framework

All of the university researchers studied in this thesis were identified because they were interacting with industry at significant level, at the very least because they were linking with industry through some form of formal mechanism. However, within this group of researchers linking highly with industry the interviews revealed that there were distinct differences in the individual practices of industrial linkage.

In chapter 4 (see 4.1.1) a crude method of categorising the ‘collaborative behaviour’ of the university researchers was developed - “linkage score”. Researchers were analysed in terms of the numbers of industry funded projects and PhD studentships they had, instances of informal contact and frequency and duration of consultancy work. Analysing the results of the survey by linkage score revealed some interesting differences between researchers, such as their understanding of what industry wanted from research linkages (see 4.2.3), but could not elucidate the qualitative differences in linkage behaviour. However when the idea of ‘collaborative behaviour’ was further explored in the analysis of qualitative interview data, a number of key factors were identified that could be used to explore the reasons behind these differences. For example, it was found that some researchers were more interested in working with industry and described themselves as industry-related researchers rather than academics. Furthermore, these researchers aligned themselves more closely with industry in terms of the level of informal contact that they had with sponsors and used information from industry to develop research projects in different ways. When compared to the literature that sought to understand the factors that explain the behaviour of researchers (see 2.5.2), it was clear that similar factors were being

identified in this study. Iterative analysis of the data in conjunction with the literature led to the identification of four factors, or dimensions, that taken together enable the understanding of university researcher behaviour. These dimensions are conceptualised as constituent parts of the ‘collaborative outlook’ (CO) framework.

The CO framework comprises two ‘explanatory’ dimensions for understanding and explaining the researcher’s behaviour: the researcher’s *institutional context* and the researcher’s *values towards industry*, and two ‘indicator’ dimensions to identify the researchers behaviour: the researcher’s *rhetoric*, and the researcher’s *action*. These are summarised in table 7.1 and described in more detail below.

Fig. 7.1 Four Dimensions of the Collaborative Outlook Framework

Explanatory Dimensions	Examples
Institutional features	Nature of research output & reputation of department Nature and location of department and university Employment history of researcher Source of funding for researcher's position Role within department (teaching/research load)
Values towards industry	Importance placed on industry feedback and knowledge Importance placed on industry uptake of results
Indicator Dimensions	
Action of researcher	Level of informal interaction with industry Source of, and influence on research directions Activity in tailoring/delivering research Level of active 'networking' with industry and other universities
Rhetoric of researcher	Linkage as a way of funding academic research Linkage as a method of technology transfer Linkage as a source of research ideas Linkage as a part of the industry

Institutional features such as the particular characteristics of the department within which researchers are located, the location of the institution and the career history of researchers are identified in this study as routes to explaining the differences in researcher behaviour and linkage activity. For example, in 4.2.1 it was identified that the projects with the highest industrial funding were located at universities with strong reputations for oil and gas research, and in 6.8 the networks that researchers’

had developed throughout their careers were identified as crucial in the generation of research linkages. Webster (1994), in his exploration of the shaping of research agendas in industry-university joint laboratories, identified that the “specific social and cognitive context within which the collaboration is located” (1994; p.130) can strongly shape the types of research that are developed. Turpin (1999) also highlights institutional features as fundamental in how linkages are developed in his analysis of university-industry linkages. The importance of the career history identified as part of the institutional features in table 7.1 is explored by Bozeman et al (2001) as a key part of their framework for evaluating the effectiveness of university-industry projects.

The institutional dimension therefore includes the factors that can help to explain the levels of involvement of individual university researchers in linkage activity.

Analysis of findings revealed that different university researchers placed different emphasis on the benefits gained from linkages. These differences in *Values towards industry*, of individual researchers were demonstrated through university researchers’ different use of industry feedback on research and the knowledge that was generated by industry and the importance that they placed upon the use by industry of research outputs. Webster (1994) used the dimension of the researcher’s ‘agency’ to explore the construction of research agendas within joint research centres where the direction of research was negotiated on a day to day basis. Researchers in this study however, had far more control of the research (due to projects being long term sponsored research) and therefore did not have to spend time “defending their interests” as did Webster’s scientists (Webster, 1994: p.129). Turpin (1999) however, did highlight the particular importance of the values of university researchers undertaking linkage with industry. Therefore, examining these values can also contribute to the understanding of the reasons behind different levels of involvement of university researchers in linkage activity.

The indicator dimensions were used to qualitatively identify researchers’ attitudes and behaviour. This is similar to the research of, for example, Rahm (1994), who classified researchers by their linkage activity. These are described below.

Exploring **researcher action** was undertaken through analysing factors such as the level of researchers' informal relations with industry, their activity in tailoring the research and their levels of active networking in the sector. Analysing these factors collectively can allow the levels of linkages activity, relative to other researchers, to be identified.

Analysis of the **rhetoric of researchers**, in their discussions of university linkage and how they justify their linkage behaviour also contributed to the classification of researchers' attitudes towards linkage activity.

Although interrelated, the two types of dimension play conceptually different roles in the framework. The two explanatory dimensions contextualise the researcher's collaborative behaviour and provide an explanation for it. These dimensions may be relatively static overtime and are closely interwoven. More dynamic are the two indicator dimensions which constitute the researchers responses to their context for linkage, as defined by the explanatory dimensions. These indicative dimensions may in turn feedback into the researchers institutional context and value framework and may slowly shift the researchers position in terms of these explanatory dimensions of CO. As such we can see that all the dimensions in the CO framework are interwoven and interdependent and, as a result, any researchers' CO framework may change over time.

A simple example of this could be as follows. A university researcher with experience as an industrial scientist (*institutional dimension*), may actively seek employment in an industrially focused university department (*action of researcher seeking particular institutional features*) as a result of the importance they place upon industry feedback (*values*). This researcher would characterise their research as being close to industry and contributing directly to industry needs (*rhetorical indicator*). This particular 'collaborative outlook' will result in the researcher 'generating' research projects of a particular nature. However, a change in any of these criteria, such as a shift in the research goals of a department, or a desire to move to less industrially focused work, may result in a shift of the overall

‘collaborative outlook’ and therefore in the nature of the research that the researcher undertake.

7.3 Classifying Researchers

The interview data from university researchers was reanalysed using the CO framework to generate example types of high, low or medium ‘collaborative outlook’ researchers. These demonstrate the interplay of different dimensions and show how the researcher’s differences in linkage activity can be revealed and explained.

Analysis of the research findings indicated that, for example, it was unlikely that a researcher classified as having a ‘low CO’ exhibited all the characteristics described in the example, indeed in some cases they exhibited some of the characteristics prescribed to a high CO researcher. However, the overall interplay of the dimensions provided a framework to classify the researchers into different types.

The three example types are presented below. These are followed by three case study examples of researchers interviewed in this study, to show how the ‘collaborative outlook’ framework can be used in practice.

7.3.1 The Low Collaborative Outlook Researcher

For the low CO researcher, the transfer of technology to the sponsoring companies was not a major priority beyond ensuring that the sponsors were kept informed of the progress of the research so as to maintain sponsorship in the future. Topics for research were unlikely to be shifted greatly to ensure obtaining funds. It was more likely that the research they were undertaking was what they would be doing regardless of industrial funding, but was potentially of interest to companies and therefore they looked to industry to provide funding. Researchers in this group did not exhibit a great enthusiasm or interest in the networking side of the university-industry linkage process. Attending, presenting and actively trying to create linkages with industry personnel at industry conferences and so on was viewed as a ‘necessary evil’ of the funding process.

The low CO researcher was likely, although this was not always the case, to be based in a discipline focused rather than industry focused department (e.g. department of earth science, rather than department of petroleum engineering), to be working in a traditional 'academic' research focused environment and to undertake little or no consultancy work. This sort of short term applied work was likely to be viewed as undesirable as it was seen to be not academically orientated enough. The outputs of work that the low CO researcher undertook was unlikely to be tailored for the industrial environment, with research papers and annual meetings to present findings to sponsoring researchers the main deliverables. They were unlikely to be keen to include practical research visits to sponsoring companies.

7.3.2 The High Collaborative Outlook Researcher

For the high CO researcher, the transfer of technology to the sponsoring companies was integral to the research projects they undertook. Although researchers were not 'slaves to the industry' in terms their choice of research topics, and did not undertake solely short term consultancy research, the research topics chosen were highly likely to be influenced by feedback from industrial personnel or in response to industrial problems. This was seen as an interesting and exciting method of idea generation and as a way of promoting new research areas that would not have otherwise been brought forward. Subsequently, the researchers with high CO were very enthusiastic about the networking process, were readily involved in activities such as conference organising, running groups and seminars within the university with industry representatives attending and in attending conferences with an aim of promoting both their department's and their own research expertise and ideas. This process added much to their enjoyment of their work and much satisfaction was gained from the dissemination of their work to industry.

The nature of the deliverables of the projects was often be tailored to facilitate the transfer of knowledge from the university to industry. Work placements were often a desired integral part of a project, with university researchers working towards, and gaining much out of, extended periods of time in industry or instances of industrialists being seconded to the university. In addition, high interaction

researchers may have spent time designing and delivering work based techniques, software or training in new technologies to industrial personnel and gained satisfaction from seeing the results of their research being implemented. This on-site work also enabled the researcher to interact more informally with industry to provide the industrial feedback that this type of researcher desires. The high CO researcher had major concerns as to the effectiveness of the communication and transfer process and if in a situation where transfer was not effective, would take steps to increase this.

High CO researchers were more likely, although this was not necessarily the case, to be located in an industry focused department such as a research institute with postgraduate teaching only or a petroleum engineering department that provided them with an environment that facilitated the researcher's inclination towards close links to industry.

7.3.3 The Medium Collaborative Outlook Researcher

The medium CO researcher fell in between the two descriptions above of the high and low types. Technology transfer was a concern for this researcher, but was not of prime importance to the projects they undertook. Their research interests were likely to be in line with the interests of industry, often by accident as much as design, and work was be tailored to fall in line with these interests. However, the industrial use of the outcomes of the research is of a lesser importance than the academic goals. As a result, the nature of the deliverables of the research projects was mainly be focused on facilitating access to traditional research deliverables, such as articles and conference papers, through industry focused university web sites and invitations to seminars in the department. This also occurred through tailoring of 'academic' research papers and results so as to make them useful to, or facilitate understanding by industrialists. These researchers did not see a great need to enhance the interaction further. This could result in a certain amount of frustration and uncertainty as to how far to tailor these deliverables.

These researchers were active in the industrial networking process, but did not necessarily have the inclination to be a driver in the industry-related conferencing circuit, had less need for the feedback of industry to shape their research foci and were slightly wary of industrial goals influencing their research too much, as this was seen to be dragging their research too far away from the purely academic.

7.4 Case Studies

To examine the utility of the CO framework for understanding researchers' collaborative behaviour, case studies of three university researchers taken from this study are outlined below. Each case makes explicit the researcher's position in regard to the dimensions of CO and uses this to explain the nature of their university-industry research linkages. The interaction of different dimensions is described after each case and for simplicity the dimensions are identified in this section by the following initials: I= Institutional, A= Researcher action, V= Values towards industry, R= Rhetoric of researcher.

Researcher A – High CO

Institutional:

A was a researcher based in a petroleum geology department as a senior lecturer. His position was entirely funded by a major oil company through a sponsored post. Although nominally in a teaching position, all of his time was devoted to research and as a result he was involved in a number of linkages outside the formal sponsorship of his post.

He spent a short amount of time in the oil industry after completing his first degree, and then went on to undertake an oil industry sponsored PhD. After a first job working in a non oil related area of geology, he felt a need to get back into oil related work and sought out a position at his current oil focused department close to the UK oil industry centre.

Industry values:

He was obviously very keen to work with industry, one of his key reasons for working in the oil sector was the scientific problems that the industry provides. He was an academic, working as part of the oil sector and responding to problems and generating basic research projects in response to these stimuli.

Action:

He was in charge of his own income generation, and acutely aware of this, as he said, "his job is dependent upon it", and suggested that as a result of these pressures he had to "reinvent himself every year or so". However, he was keen to remain working in a particular scientific area, as he was aware that his continuous research experience and reputation were key attractions to potential sponsors. He developed a formal strategy document for himself and

his colleagues to assist in the generation of industrial funding, which outlined methods and tactics for building up relationships and linkages with industry, which if followed it was hoped would smooth the way to attracting long term linkage projects. Outside of formal linkages, he was very keen to maintain informal links with industry figures and would happily offer free advice to them over the phone or through short meetings, which can be easily arranged due to his proximity to the industry centre.

He had a great deal of contact with industry, yet he deliberately distanced himself from undertaking work that was responding to the direct short term needs of industry and produces “cheap and dirty research” creating working models of oil fields and so on. The work he undertook was always of a ‘basic research’ nature, in “understanding mechanisms and predicting certain things from data”, but was of use to industry. Along with the normal academic outputs of reports and papers, he also regularly visited company sites to offer expertise.

Rhetoric:

“I would have difficulty in saying that I was a slave to the needs of the oil industry, we respond to certain needs. What creates those needs is often something that we might have discussed with someone [from the oil industry] the day before.”

If the particular features of the different dimensions that make up Researcher A’s CO are closely examined, the importance of their interplay becomes apparent. The importance A placed upon interaction with industry (V), meant that he networked extensively with industry (A). This networking was facilitated by the location of the department near to the oil industry centre and its oil focused reputation (I). He maintained his research expertise in a particular area (A) and this extensive experience and expertise made him attractive to industry sponsors, through which he discovered potential areas of investigation (V) and was able to suggest ideas for new sponsored projects and gain funding for his post (A). Subsequently, this sponsored post meant that his role within his department had become solely research based (I). He described his research as responding to the needs of industry, but not as a slave to them (R) and this view both described and reinforced his research activity.

Researcher B – Low CO

Institutional:

B was a senior researcher at a general earth science department in a highly prestigious university. Her post was funded by external research income, which mainly came from the industry through a major research project. She spent no time in industry and has been based at this university since her undergraduate studies began.

Industry Values:

For this researcher, the oil industry was seen as important a source of funding and of data to use in her research, but she was academically orientated. She rarely visited company sites to assist in the transfer of knowledge, and did not have great concerns over how the research output was used by industry, beyond ensuring that they maintained sponsorship.

Action:

She was in charge of her own research income, and was originally part of a research group that undertook short term analysis projects that industry had come to the university to undertake. The group as a whole felt that work was academically dissatisfying and produced the current research project [then in its second three year phase] to address more theoretical issues that they were interested in. This project was of less direct short term use to the oil companies, but the existing contacts were used to gain a large number of sponsors for the project.

Although she viewed networking at conferences as a part of her role as an industrially sponsored researcher, she had little contact with sponsors outside formal meetings, and did not enjoy the process of chasing up potential sponsors in attempts to gain or maintain funding. The main source of informal linkages to industry was through ex-PhD students. The research outputs of the work that she undertook were not greatly tailored for industry, and she found that industry was “not always sure what they want”

Rhetoric:

“We have to get something out of it that we want...that can be a research paper, an improvement in facilities, funding more people or access to data. We have definitely done things with oil company money that has raised the level of our research. The key thing is to give them what they want, even if it is something that you are not doing all the time, don’t neglect the fact that they need something out of it”

Examining the interplay of the dimensions, Researcher B had a limited interest in industry (V), which reinforced her lack of interest in networking (A). In addition the reputation of the department and university as centres of excellence (I) facilitated the acquisition of sponsorship and enabled her to follow her own, rather than industrially suggested, research directions (A). This was reflected in her characterisation of the deliverables to industry as outputs that have to be undertaken in addition to the projects, rather than as an integral aspect of the work (R).

Researcher C – High CO

Institutional:

C was a researcher based in a industry focused petroleum geochemistry institute, located away from the industry centre. He was part of a small group of researchers who were well known in the industry for producing high quality industrially relevant research. Most of their research income came from industry sponsorship and the institute had, in the past, had an industrial liaison group that supported and guided the research in general, and enabled contacts to be maintained. He worked for a major oil company for seven years before moving to his current department 12 years ago, and still maintained close links with his previous employers.

Industry Values:

He felt very strongly that there was a need to improve the technology transfer between universities and industry, and would like to see sponsors allocating resources towards ensuring the outputs of research were more directly incorporated into working practices. He preferred to work on bilateral projects (rather than JIPs) for this very reason, as it gave him the opportunity to create closer ties with one company, spend time with them and ensured that technology was transferred effectively to them. This type of link also provided him with the opportunity to learn from them and gain information that could steer his research in the future.

Action:

There was no formal strategy for generating research income besides “beating people over the head to do as much as possible”, but he had created and maintained good links with industry. This was mainly done through personal contacts, and he regularly spoke to industry figures informally over the phone and email. He felt that regular contact with industry sponsors was important so as to gain an impression of what is important to them so as to be able to create attractive and useful projects, but suggested this is difficult due to his location away from the industry centre. A wide variety of research was undertaken at the institute, varying from long term ‘blue skies’ work with a range of companies through to small, one day consultancy projects to analyse particular data for individual firms, although the majority of his work “lies somewhere in the middle”. He was also considering moving into marketing the more commercial outputs of his research directly to companies, such as selling analytical services or software.

Rhetoric:

He viewed linkage as a partnership that could be improved, rather than purely a way of funding his own research ideas. “...so this is not me sitting here thinking ‘I don’t give a shit about what happens in the industry’, I actually like involvement with them very much. The interaction and helping to solve problems is something I personally like very much indeed. I would not want to work in a vacuum [away from industry].”

Examining the interplay of dimensions, Researcher C’s long experience with industry (I), meant that he had many contacts who he was keen to maintain contact with (A). He felt that his work should be important and useful to industry (V) and as a result was attempting to tailor his work commercially (A). He indicated that the location of his department made direct personal contact with sponsors difficult (I), but he attempted to spend as much time as possible in companies to both transfer knowledge to, and receive information from, industry (A). He characterised himself and his research as part of the industry (R).

7.4.1 Discussion: the Interplay of Dimensions

This examination of the three researchers through the use of the framework of the collaborative outlook has shed light on the interplay of the different dimensions of collaboration and how they influenced the research of individual researchers.

The different aspects of the researchers' environments and their attitudes towards industry contribute towards their linkage activity and the way that they qualify and legitimate their methods and range of links. The descriptions of this interplay in the examples above were by no means exhaustive of the effect that the dimensions had upon each other and are presented as examples rather than full investigations of this process.

Each of the three researchers described exhibited subtly different methods of interacting with industry. For example, all of their research agendas were industrially influenced as a result of sponsorship, yet it can be seen very clearly that the collaborative outlook of the individual researcher influenced exactly how this was done. This was exemplified in the first two researchers described above. Researcher A used his location in an oil related department close to the industry centre, his skills at networking, contacts and enthusiasm to work with industry to be able to pick up on industry issues and problem areas to which he could apply his expertise. He did not wait to be approached to solve these problems, the project proposals were created by him and developed in close discussion with industry. Researcher B interacted less with industry and selected her current research from academic stimuli within her research group, with limited input from industry contacts. The university's reputation of excellence made it easier for her to persuade sponsors to support her work, even though industrially relevant project outcomes were less integral to the project.

Both the researchers tailored their work for industry yet due to their differing 'collaborative outlooks', industry influenced the construction of research projects at different stages. For Researcher A, industrial problems were key stimuli for the research project and the needs of industry were in-built from the beginning of the

project. This top-down method of tailoring contrasted greatly with the more bottom-up method of Researcher B. For this researcher, tailoring to meet industry goals occurred at a much later stage and was not as important in the overall set up of the project.

Similarly, the 'collaborative outlook' of researchers affected the importance and therefore potentially the success of the technology transfer process within collaborations. Researcher C, who had a high CO, worked in industry for many years, was currently working in an industry focused department and enjoyed working very closely with industry on projects. As a result, he was very keen to maximise transfer, concerned about the efficacy of the process and subsequently worked closely with companies, visiting their sites and developed his work to be more accessible to them. Researcher B, had a much less industry focused outlook and for her, transfer was not a key issue beyond ensuring that the sponsors were kept happy enough to remain funding the work.

Although this was not explored in this thesis, as it would have required a study over a long time period, the interplay of the different dimensions of collaboration mean that the collaborative outlook of any particular researcher was not fixed and could change over time. This could be as a consequence of a change in their institutional environment, an alteration in their level of contact with industry, or due to a shift in their values towards industry, thus creating subtly different linkages and interactions with industry. For example a researcher with a low CO may move to a department with a strong industrial research strategy and better links, and as a result have much more contact with industry, potentially creating projects that are closer to industry goals. This may cause a shift in the way that they describe their research work and aims and their rationale for choosing particular types of projects.

The relative importance of any particular factor or dimension was difficult to assess and would require further research specifically focusing on the framework.

However, the research suggests that different factors may be of differing importance in certain situations, indeed in some cases one factor may have an overriding effect upon the whole collaborative outlook of a particular researcher. For example, as was

suggested in 6.2, many young or new researchers to the field find it very difficult to begin to build up a network of contacts (and subsequently gain sponsorship for research) without a gatekeeper or mentor in the department. These researchers may be very keen to transfer their research to industry, but are prevented by this lack of contact. Here the institutional and researcher action dimensions interplay to restrict the researchers potential for linkage.

In other examples the key dimensions or factors were more difficult to unpick from the overall 'collaborative outlook'. The two researchers with the lowest COs that were interviewed for this thesis (one of which is described above) come from the same department, yet it would be difficult to suggest that the nature of the department within which they work is the main reason for this, although it is not directly petroleum focused. Indeed, both researchers may have actively located themselves within this particular institutional environment so as to maintain their linkages with industry more 'at arms length' than other researchers (this information was not gathered from the informants). Conversely, the department may have focused them more on academically focused work. This again highlights the importance of the interplay of factors and dimensions.

7.5 Conclusion

This chapter has developed the 'collaborative outlook' framework to investigate the collaborative behaviour of research scientists linking with industry and in doing so has examined the different factors that interplay to shape research linkages in this sector. The description of three researchers utilising this framework has shown how the environment, organisational structures, experience and attitudes to industry of the researchers affect the way that they undertake research linkage with industry. This encompasses the key findings from this thesis described in 6.8 including, networking and informal linkages, the generation of research topics and methods of gaining funding, through to the nature and organisation of projects, the project outcomes and the methods used to transfer the knowledge to the sponsoring companies.

This process has demonstrated that the individual researcher and their collaborative outlook plays an extremely important role in the entire linkage process, from the choice and aims of projects through to the efficacy of technology transfer. However, as has been shown in this chapter, university researchers do not operate in a uniform way. Their differing collaborative outlooks describe different methods and preferences in undertaking research linkages and this must be accommodated for and understood in the building of effective research relationships between university and industry. In addition, the importance of the interplay of the four dimensions and their constituent factors that has been exhibited in this chapter, suggests the possibility that both individual researchers and university departments could utilise this framework to help examine and enhance their linkages with industry. However, it is important to recall that trust and mutual respect are vital ingredients to successful linkage (Davenport et al, 1999), and forcing researchers to change their methods of operation may cause ill feeling and prevent build up of trust.

As identified in 6.8, university informants in this study indicated that different university sponsors also have different methods of operating in linkage. These industry contact were identified as 'hobbyists' or 'sponsors'. The development of the framework in this chapter has focused on the university researchers, but with further research it would seem possible to develop a similar framework for industry researchers.

8. Conclusions

8.1 Introduction

This study explored university-industry research linkages in the North Sea oil and gas sector through both a survey of university researchers and qualitative interviews with university and industry researchers. Analysis of the findings led to the identification of a number of key factors influencing the nature of university-industry linkage in the oil and gas sector. These were: the importance of informal linkages and networking in university-industry research linkages, the range of benefits and barriers to linkage activity for both university and industry, the characteristics of linkage activity that are particular to the oil and gas sector and the influence of the behaviour and attitudes of individual researchers on their linkage activity. A framework was developed, the 'Collaborative Outlook', to explain these differences and this is a key development in the area of understanding the behaviour of researchers involved in linkage.

The conclusions to this thesis are presented in four key sections. In 8.2 the value of conceptualising linkage as a relationship is highlighted. In 8.3 the role of the individual in shaping linkage is considered and the value of the Collaborative Outlook framework developed in Chapter 7 to understanding linkage discussed. The findings particular to the oil and gas sector are discussed in 8.4 and conclusions relating to this sector are drawn. Finally, the implications of the research for good practice in linkage across sectors, universities undertaking oil and gas related research, oil and gas companies and policy are presented in 8.5.

8.2 Linkage as a Relationship

The exploration of linkages in this thesis has highlighted that both university and industry researchers contribute to and gain from research linkages. Chapter 5 described a range of direct benefits (e.g. research funding and publications for the university and research outcomes for industry) and indirect benefits (e.g. access to industry knowledge for university researcher and staff recruitment for industry) that can be gained by all those involved in linkage. This reinforces the understanding

from recent studies of innovation and linkage (e.g. Klein, 1991 and Scott et al 2002) that linkages do not operate as one way or linear flows of knowledge from university to industry, but as two way exchanges of knowledge and ideas (see 2.2.2).

Thus, it can be argued that linkage is best conceptualised as a relationship between university and industry, as opposed to a 'product' that can be bought by industry or as straightforward route to gain additional income for the university. Whilst previous research has implicitly recognised the importance of relationships in linkage, it is vital to the development of good practice in this area that the understanding of linkage as a relationship is made explicit. This is discussed further in 8.5.

The interviews undertaken in this thesis highlighted the importance of good relationships between university and industry researchers in undertaking successful linkage. Many industry and university figures interviewed indicated that linkages had been formed with ex-colleagues, friends they had studied with at university, or with contacts they had met through chance meetings or at conferences. Therefore it is unsurprising that good relationships were found to exist between university and industry in this sector. This was characterised by the mutual trust, professional respect and understanding identified by researchers such as Senker (1990) and Dill (1990) as essential ingredients to successful linkage. This finding highlights the importance of interpersonal networks and informal interactions to both generating linkage in this sector and in the transfer of knowledge.

8.3 Individuals and Linkage

Conceptualising linkage activity as a relationship between university and industry highlights the importance of understanding those individuals undertaking linkage. To fully understand how relationships operate, it is vital to explore the individuals undertaking them. Individuals were found to be crucial as routes through which informal interactions occur and through which technology and expertise can be exchanged. Therefore, linkage activity cannot be viewed as a vehicle for technology transfer that will operate independently of the researchers that are involved in these linkages.

A key finding of the thesis is that individual factors are central to explaining differences in linkage activity between university and industry researchers. That the importance of individuals was identified so strongly may in part be explained by a research design which examined linkage at the individual, rather than organisational level. In addition, in undertaking a single sector study with the majority of linkages occurring between large companies and universities in one technological area (geoscience), a number of the factors identified in the literature as shaping diversity in extent of linkage (i.e. technology, firm factors, and sectoral factors, as discussed in 2.4) were removed. Therefore this study may have highlighted the importance of individuals more than would be the case in a cross sector study. However, these factors merely create the context in which individuals undertake their linkage relationships. As a result, the importance of individuals explored in this thesis and identified in other research (e.g. Rahm, 1994; Santoro and Chakrobarti, 2002; Butler and Birley, 1998), confirms that the characteristics of individuals are fundamental to successful research linkages. Exploring the reasons why individuals have different attitudes to linkage has been a key aspect of this thesis and extends the understanding of linkage through highlighted the interrelationship of key factors that shape the behaviour of researchers in linkage (outlined in 8.3.1. below).

This study of the oil and gas industry proved an interesting location to explore the importance of individuals in linkage. In particular this was because, contrary to the findings from the literature discussing the motivations of university researchers in undertaking linkage activity across sectors (e.g. Charles and Conway, 2001; Howells et al., 1997), a large number of researchers in this sector indicated that they found the problems of industry both interesting and productive in terms of their research (this is discussed further in 8.3.2). As a result of this keen interest in linkage by university researchers, these informants were enthusiastic to discuss their linkage activity, the reasons why linkage can be problematic, why linkage activity was valuable and what individuals sought to gain from linkage. This facilitated the collection of a rich supply of data from university researchers on their attitudes and behaviour to linkage and from this the 'collaborative outlook' framework was developed to explain their linkage behaviour.

The issues related to individuals from university are discussed below and are followed by the findings relating to the different attitudes and behaviour of industry researchers that have been identified in this thesis.

8.3.1 University Researchers and their ‘Collaborative Outlook’

The ‘collaborative outlook’ framework, described and developed in Chapter 7, not only provides a route to classify university researchers studied in this thesis by their linkage behaviour (similar to, e.g., Rahm, 1994 and Santoro and Chakrobarti, 2002), it also helps to understand the reasons behind why some appear to be more closely aligned to industrial research linkage than others – an area that is underdeveloped in the literature of university-industry linkages (see 2.5.2).

The framework and the examples explored have demonstrated that qualitative interviewing techniques can be used to explain differences in linkage behaviour through exploring university researchers attitudes and motivations towards linkage. An exploration of these factors enabled not only the classification of researchers into those having high, medium or low ‘collaborative outlooks’ (CO), but also the reasons why an individual researcher developed any given level of CO to be understood and how a change in, for example institutional environment, experience of linkage or network of industry contacts may affect this. This framework is valuable because it extends the current understanding of the behaviour of university researchers involved in linkage – a central aspect of understanding the relationship between university and industry researchers.

8.3.2 Industry Researchers: ‘Hobbyists’ and Sponsors

It was apparent from the analysis of the interviews with university and industry informants that there were also similar variations in the industry researchers and the importance and effort they placed on university linkage. This study did not collect enough in depth data to develop a ‘collaborative outlook’ for industry contacts, due to the difficulty in locating industry respondents and their lesser input to projects relative to university researchers. This resulted in data from industry respondents being less rich than those obtained from university researchers. However, it is clear

from the research that there are differences in the attitudes and perspectives amongst those on the industry side of linkages and that these also affected the characteristics of linkage that they undertake. Instances were identified in the interviews where factors such as career histories (such as previous work experience in university), previous experiences in linkage with university researchers, and company or institutional environments influenced linkage behaviour.

These factors enabled industry researchers to be classified into two different ‘types’ of industry contacts, as identified and discussed in Chapter 6 – those that could be classified as ‘hobbyists’, that is those who took an active interest in linkage activity beyond the remits of their job and those that purely acted as sponsors of projects, doing little beyond attending meeting and delivering funding.

The hobbyists, analogous to the high ‘collaborative outlook’ university researchers, generated better relationships with university researchers as their active interest meant that they were willing to put the extra effort in maintaining contacts, sourcing data, giving feedback and steering research in the direction that they were most interested in. Those that behaved more as ‘sponsors’ gave limited input into the projects and had little informal contact with university. This distinction was particularly identified by the university researchers running Joint Industry Projects (JIPs) as these provided comparisons between the different industry contacts supporting their projects. Those industry contacts that were more engaged, the ‘hobbyists’, through providing data and guiding research through feedback had more interactions with university researchers, more opportunities to gain from research findings and informal feedback, and unsurprisingly as a result had a better relationship with the university researchers.

Many of the characteristics of linkage in the oil and gas sector have been identified in university-industry linkage in other sectors – in particular the importance of informal linkages in the transfer of knowledge and in generating research linkages.

Consequently, although the ‘collaborative outlook’ framework for university researchers and identification of ‘hobbyists’ and ‘sponsors’ in industry researchers, is based on findings from this study of the oil and gas sector, there is no a priori reason

to presume that these findings would not also be relevant to the understanding of university-industry linkage in other sectors. Indeed, it would be an interesting exercise to apply the 'collaborative outlook' framework to university researchers in other sectors and to explore further the 'dimensions of collaboration' with industry contacts in both the oil and gas and other sectors.

8.4 Oil and Gas Sector Specific Conclusions

The findings and discussion presented in this thesis has shown that university and industry researchers in the oil and gas sector face many of the same pressures as those seeking to link in other sectors. However the study has shown that linkage in this sector has particular characteristics. These are presented below.

8.4.1 Level of Linkage Activity in the Sector

It was identified in the introduction to this thesis that the small number of studies that have provided insights into university-industry linkage in the oil and gas sector (Bower and Keogh, 1996; Salter et al 2000), indicated that linkage opportunities were high relative to other sectors and that university knowledge had much to contribute to industry. The findings in this study also suggest that linkage activity is high in this sector, with the results from the survey in particular emphasising this point. The survey identified that approximately three-quarters of university researchers involved in linkage were working on all of the following forms of formal linkage; industry sponsored projects, supervising sponsored PhD students and undertaking consultancy. All bar one of the respondents were involved in sponsored research.

The university and industry researchers indicated that, in general, there was a good working relationship between them. The different attitudes of university and industry researchers (see 8.3 above) resulted in different types of relationship between partners in linkage and subsequent variations in the levels of informal interaction and understanding. However, the findings from this survey seem to suggest that, contrary to the indication by the Royal Society of Edinburgh (1997), the majority of the university and industry researchers understand each others needs and capabilities.

Variations in understanding were identified, resulting in frustration on the part of both university and industry researchers, but predominantly the relationship and understanding was good.

Those academics based in Aberdeen, the main centre of oil and gas companies in the UK, indicated that local contacts were useful in maintaining these relationships as they could 'drop in' to companies easily to exchange information or offer advice. Similarly it was easier for industry contacts to accept invitations to come into the university for presentations. Dill (1990) reported that geographical proximity such as this was critical in maintaining research networks. However, the level of informal interactions between academics from universities based away from Aberdeen were similar to those in Aberdeen, suggesting that in this case geographical location was not a major factor in maintaining a research network in this sector.

8.4.2 Importance of Linkage for University Researchers

A major finding from this study of university-industry linkage in the oil and gas sector was that university researchers found informal interactions, both within and outwith, formal linkage activity hugely beneficial to the development of new ideas and areas for research. It was reported by many university researchers that they enjoyed working on industrially related problems and actively engaged with industry contacts informally to develop these ideas.

The use of industry contacts to develop research ideas was not explicitly identified as a motivation for university researchers engaging in linkage activity by the existing research literature (e.g. Howells et al, 1998; Charles and Conway, 2001). This is particularly interesting as it demonstrates that this sector is a productive and interesting environment for research linkage between university and industry – indeed one of the barriers to linkage identified by Howells et al (1998) was that university researchers did not find industrial problems interesting. University researchers also found gaining access to 'real-life' industry data particularly useful in their research, which was identified by them to be of high quality due to the investment of the oil firms in developing their exploration techniques. This may be

particular to this sector due to the large investments in data collection by oil and gas firms.

It would be surprising if university researchers in other sectors, particularly in those that have high opportunities for linkage (e.g. pharmaceuticals), did not gain ideas for research from industry or indeed find the problems of industry interesting. That this finding is not made explicitly in the existing literature, emphasises its particular importance in this sector. This also highlights the fact that little research attention has been paid to understanding why and how university researchers link with industry. Much of the research exploring motivations of university researchers for undertaking linkage has been gained from research conducted with Industrial Liaison Officers (e.g. Howells et al, 1998; Charles and Conway, 2001 (in part) and Klofsten and Jones-Evans, 2001), rather than university researchers themselves. This suggests that findings relating to university researchers being interested in the research problems of industry may be identified if research is conducted with university researchers, rather than ILOs.

8.5 Implications

The findings presented above have a number of key implications. These will be discussed below in the following areas; implications for university-industry linkages in general, implications for universities undertaking oil and gas research, implications for companies in the oil and gas sector and policy implications.

8.5.1 Implications for Linkages in General: Good Practice

The discussions above, highlighting the importance of understanding university-industry research as a two-way relationship between individual researchers with different attitudes and behaviour, has implications for understanding good practice in linkages in general.

The exploration of different attitudes and behaviour of university and industry researchers in this thesis demonstrates if the outcomes of linkage to university and industry are to be maximised, industry engagement with university research cannot

be viewed as a straightforward procedure where research is funded by industry, undertaken by university and outcomes produced at the end of the funding period. This study shows that those industry contacts and university researchers who are invested in the research – those that were ‘hobbyists’ from industry, or academics who had a high CO – put in extra efforts as research champions (cf. Hicks, 1993; Senker, 1990) to ensure the project was successful. Industry champions, for example, took steps to ensure that industry needs were inputted into projects through regular informal interactions, collected data for use in the research and provided feedback on research findings. University champions similarly ensured that regular informal interactions were undertaken with industry contacts and that the research findings were made relevant to the needs of industry. With champions on ‘both sides’ of the linkage, the crucial informal interactions were much more likely to occur on a regular basis enhancing the benefits to both university and industry of linkage activity.

If the opportunities for linkage are to be maximised, it is therefore important to develop routes through which individuals can be encouraged, supported and ‘grown’ into ‘hobbyists’ from industry, or high CO researchers from university. The ‘collaborative outlook’ framework has demonstrated that changes in institutional context and job specification can change the CO of a researcher and their relationship with industry.

Although this was not undertaken in this study, the ‘collaborative outlook’ framework described in Chapter 7 could be applied to a whole university department (or indeed to whole universities) in order to assess the skills and attributes of researchers, both individually and collectively. This could assist in improving the ability of a department to link with industry by using CO evaluations in a number of ways. For example, if there are a large number of researchers in a department with a ‘high’ CO, these could be encouraged to promote high profile conferences or research meetings to capitalise on their good networks with industry. If there were ‘low’ CO researchers who were identified as not wishing to link with industry, these should not be forced into linkage activity or be the contact for industry if working on

a project. Conversely if researchers with a low CO were interested in developing linkage, they should be allocated a high CO mentor from within the department so as to enhance their linkage opportunities and informal networks. The CO framework therefore could be used as a tool to develop *informed* departmental research strategies that could maximise the linkage activity of departments.

Developing routes, such as conferences and seminars, and providing the time (particularly for industrialists) to attend these events is a key route through which academics and industrialists can have the opportunity to interact with each other, establish and strengthen their network of contacts, increase mutual awareness of each other's research needs and build the trust essential for effective linkages. This recalls Faulkner and Senker's (1995b) description of a 'dating agency', as opposed to a 'marriage brokerage', approach as the most effective route to generating links between university and industry.

The interface between university and industry will always be a relationship and therefore any linkage will always require some form of relationship building. In this study of the oil and gas sector, the informal relationships have been identified as being hugely important in generating linkages. It is however important to note that this importance and strength of informal linkages may vary across sectors.

8.5.2 Implications for Universities Undertaking Oil and Gas Related Research

This study indicates that universities undertaking research relevant to the oil and gas sector are well placed to capitalise on their expertise through research linkages with industry. University researchers are excited by the research undertaken in linkage and there appears to be a good network of university researchers and industry contacts that engage with each other through amicable relationships in order to develop research.

However, the study also indicates that the research network is small, and that new researchers or departments wishing to engage with industry in the sector may find it

difficult to interact with these networks. The importance demonstrated in this thesis of personal relationships in generating formal linkages suggests that the best way to become more engaged in these research networks is through conference attendance, maintenance of contacts with alumni in the oil and gas sector and the recruitment of staff from industry. All these activities are likely to improve the frequency and number of interpersonal links to the industry and subsequently increase the likelihood of formal linkage activity. The importance of alumni and recruiting from industry is of particular importance in the oil and gas sector due to the high relevance of university research work to the direct needs of industry and can be developed through, for example, the development of industry related courses in universities.

The research identified that Industrial Liaison Offices (ILOs) were not seen as useful routes for attracting research linkages in the oil and gas sector. Although not studied in depth in this thesis, ILOs act as intermediaries between university and industry to assist in the generation of linkage, but informants found that these were often 'in the way' of direct relationships between university and industry researchers – a key route to effective and successful linkage identified in this thesis. This was also identified by Faulkner (1995) in the pharmaceutical sector and may be a finding particular to high linking sectors and resulting from the good relationships that exist between university and industry researchers within them. However, since informal interactions have been identified as important in research on linkage in other sectors, this finding could be relevant to other sectors – particularly as many studies have used ILOs, rather than academics, as the prime source of data. Consequently there may be scope to explore that use of ILOs as bodies to support university researcher liaison, rather than to act as the intermediaries themselves.

8.5.3 Implications for Oil and Gas Companies

As indicated in 8.5.2, the interest of university researchers in the problems of industry demonstrates that there is considerable scope for the oil and gas industry to access relevant research expertise within universities. However this research, in identifying differences in the ways in which different industry contacts interact with

those in universities, has demonstrated that the benefits gained from linkages are strongly influenced by the individual industry contacts.

It was clear from this research that those industry contacts who were more engaged with university gained more from research linkages through informal interactions and were able to steer research projects to gain the results they wanted. It was also identified that many of the industry contacts that were engaged with linkage projects, were undertaking these activities as a hobby outside their job remit. Therefore if industry is to maximise the benefits from linkage with universities, it should ensure that staff are allocated time to spend networking through activities such as conference attendance and actively monitoring projects with university researchers.

The ITF offered the opportunity for industry to create linkages outside these informal networks and for those academics who do not have access to the network to become engaged with industry. There were mixed responses from university researchers in using this route to funding, with some disliking the reduction in direct contact to sponsors or preferring to use their existing networks. Others felt that the system was good because it may lead to research projects being sponsored on merit rather than on the basis of friendly contacts. The lack of responses to calls for projects indicated by industry sponsors, and the limited awareness of university respondents of ITF, suggested that further work needs to be done by the organisation to make this a fully effective intermediary in the research process

The Energy Intermediary Technology Institute (ITI) was set up in Aberdeen in late 2003, specifically to enhance the transfer of technology between university and industry. The data collection for this study was undertaken before this Institute had been announced, so it is difficult to assess how this will affect university-industry relationships in the sector. However, this research echoes the findings of Faulkner and Senker (1995b) who identified that to generate the trust and understanding, and therefore the most productive and successful linkages, the ITI should develop ways to encourage university and industry researchers to network along the lines of the 'dating agency' approach.

8.5.4 Implications for policy

This research has shown that in depth qualitative interviewing can enable researchers to explore the reasons why individuals have different attitudes and different behaviour towards linkage. Using this approach in the oil and gas sector has furthered the understanding of how researchers undertake linkage. Given the importance of individual interactions in other sectors, it would be interesting to assess if frameworks such as the 'collaborative outlook' could be applied successfully to other university-industry linkage settings.

The importance of relationships and informal linkages cannot be understated in this sector and this has particular significance for studies of university-industry linkage in general. Although it would be interesting to undertake equivalent studies in other sectors (particularly those with few links to industry) this research has indicated that, if a deeper understanding of linkage is to be gained by researchers and policymakers, studies of university-industry linkage should ideally be undertaken symmetrically. That is, those directly involved in the projects from both university and industry should be studied. The majority of studies have only looked at industry (e.g. Faulkner and Senker, 1995b) or university (e.g. Rahm 1994; Charles and Conway, 2001).

Much research on the academic side has been identified that uses Industrial Liaison Officers (ILOs) as respondents in studies, rather than university researchers themselves. If the aim of a research project into university-industry linkages is to further understanding of linkage in a particular setting, then ILOs cannot provide detailed information on how the important relationship between researchers operates, nor the full range of actual benefits. In addition, talking to ILOs, whose primary role is often to generate research income, may reinforce a linear-model understanding of university-industry linkage.

This thesis has indicated that the crucial role of the interactions between individual university and industry researchers can be underestimated in large scale surveys of linkage activity that are used to inform policy (e.g. Charles and Conway, 2001;

Howells et al, 1998) This understanding can be used to inform further policy oriented research into university-industry research linkages.

It is encouraging to note that in the recent Lambert Review (Lambert, 2003) into research linkages, the 'most exciting' linkages were identified as being made by like minded people coming together to undertake research and the importance of networks of university and industry researchers were identified. However, the vital importance of informal interactions in and around linkage demonstrated in this study is not emphasised by Lambert and there is scope to explore these further to influence policy.

There is considerable scope for policy incentives that enable university and industry researchers to build up a relationship to generate trust and mutual understanding to be encouraged. Existing mechanisms such as CASE Phd studentships, KTP (formerly TCS) schemes all facilitate this process. The development of further mechanisms, such as funding university researcher placements in industry to allow academics to build up their network of contacts, would assist in this process.

Finally, as revealed in the literature review, it is important to be aware of the use of terms when discussing linkage. Much of the research seeking to inform the policy on university-industry linkages uses the term 'research collaboration' (Lambert, 2003; OST, 1999; Salter et al, 2000) and indeed as this study has shown, successful research does involve collaborative behaviour from both sides, but in the majority of cases university-industry linkages are based on university run consultancy or project work. This research has demonstrated that it is important that that policy-makers and researchers undertaking studies to inform policy in this area explore linkage as a collaborative endeavour, but emphasise that collaboration through the exchange of knowledge, ideas and information occurs predominantly out of the efforts, attitudes and behaviour of those involved in linkages, and not as a result of the linkage mechanism itself.

8.6 Concluding Remarks

The aim of this thesis was to explore university-industry research linkages in the oil and gas sector. Specifically the thesis sought to ascertain the nature and extent of research linkages, the benefits of, and barriers, to linkage and the importance of individual researchers and their institutions in linkage. Furthermore, the study sought to identify good practice in linkage in the sector and in university-industry linkage in general.

This thesis makes a substantial and novel contribution to understanding of the oil and gas sector by documenting linkage and identifying the benefits and barriers to linkages for both university and industry. Linkages in the oil and gas sector are based on relationships between individual researchers. This thesis has shown that understanding the behaviour and attitudes of individual researchers is vital to understanding linkage more broadly. If university-industry linkage is to be maximised, both in this sector and more generally, policymakers and those involved in linkage must ensure that mechanisms for generating linkage build respect, trust and mutual understanding between researchers from university and industry.

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Appendix A. Survey Questionnaire

University – Industry Collaborative Research in the North Sea Oil and Gas Industry



University – Industry Collaborative Research in the North Sea Oil and Gas Industry

This questionnaire should take no more than **10-20 minutes to complete**, depending upon the extent of your interactions with companies involved in the upstream North Sea oil and gas industry.

For the purposes of this questionnaire the 'oil industry' shall be taken to cover any company involved in North Sea oil and gas exploration and production, including:

Operators / Major Oil Companies
Contractors
Consultancies
Supplier SMEs

CONFIDENTIALITY:

All data collected from this questionnaire will remain anonymous. No individual will be identified within the research output. Questionnaires are numbered for control purposes, and so there is no unnecessary follow up with researchers who have already responded.

This research forms part of a PhD research project, funded by the Economic and Social Research Council. Some assistance for this survey comes from Shell UK Exploration and Production.

FEEDBACK:

Research findings will be circulated to all respondents requesting it. Please insert your email address in the space provided at the end of the questionnaire if you require a summary of findings.

Should you have queries about any element of the research please do not hesitate to contact the research co-ordinator at the address below:

Mr Alex Hilliam
Science Studies Unit
University of Edinburgh
21 Buccleuch Place
Edinburgh
EH8 9LN

Direct Telephone 0131 650 4261
Email Alex.Hilliam@ed.ac.uk

1. BUILDING COLLABORATIVE RESEARCH WITH THE OIL INDUSTRY

1.1 Does your department have a strategy for obtaining oil industry research funding?	Yes / No
--	-----------------

1.2 What steps do you take to stay in touch with, and understand the research needs of, the oil industry?	Please tick
Conferences	
Informal meetings/contact with members of industry	
Formal meetings with members of industry	
Industry literature	
Other	
Please state:	

1.3 Please indicate (from your experience) the effectiveness of each of the following methods of attracting oil industry funding?	Very Effective	Effective	Rarely Effective	Not used
Personal contacts				
Meetings at conferences				
Focused presentations (e.g. open dept. meetings)				
Speculative proposals to companies				
ILO (Industrial Liaison Office of University)				
Other				
Please state:				

1.4 Do you perceive that there any barriers to acquiring oil industry funding?	Yes / No
If yes, please describe briefly:	

1.5 Do you tailor your research to meet the oil industry's needs?	Please tick
Completely	
To a considerable degree	
Slightly	
Never	
Please briefly describe, in general terms, the nature of any changes.	

1.6 Where you do tailor research to meet industrial needs, what do you feel is the impact of this on your research?	Please Tick
	Positive
	Neutral
	Negative
Please elaborate if not neutral:	

2. TYPES AND EXTENT OF COLLABORATION

2.1 Industry Funded Consultancy

2.1.1 Do you undertake any consultancy work for the oil industry?	Yes / No
---	----------

If No, go to section 2.2

2.1.2 Approximately, how often do you undertake consultancy work for the following types of company?	No. times per year
Oil operators	
Oil contractors	
Oil consultancies	
Oil SMEs	
Other	
Please state:	

2.1.3 What is the typical duration of the consultancy work?	
---	--

2.2 Collaborative / Sponsored Research Projects

2.2.1 How many (wholly or partly) oil industry funded research projects are you currently involved in, or have been involved in the last three years?	
---	--

If 'None' – please go to section 2.3

2.2.2 Please describe each of the oil industry funded projects below:

Space is provided for the description of up to three projects. If you are involved in more than three such projects please describe the three largest/most recent.

Project (A)	Title/Subject area:	
	No. Staff working on project	
	No. PGs working on project	
	Duration of project	
	Approx. value of funding (£000 per year)	
	No. of sponsors	
Please list sponsors:*		
Main Research Outcomes (expected or actual):		

**If possible please list all companies/ research councils etc. sponsoring the project, or if this information is sensitive, list the different types of sponsoring organisations involved – refer to list of 4 main company types described in the introduction to the questionnaire.*

Project (B)	Title/Subject area:	
	No. Staff working on project	
	No. PGs working on project	
	Duration of project	
	Approx. value of funding (£000 per year)	
	No. of sponsors	
Please list sponsors:*		
Main Research Outcomes (expected or actual):		

Project (C)	Title/Subject area:										
	<table border="1"> <tr> <td>No. Staff working on project</td> <td></td> </tr> <tr> <td>No. PGs working on project</td> <td></td> </tr> <tr> <td>Duration of project</td> <td></td> </tr> <tr> <td>Approx. value of funding (£000 per year)</td> <td></td> </tr> <tr> <td>No. of sponsors</td> <td></td> </tr> </table>	No. Staff working on project		No. PGs working on project		Duration of project		Approx. value of funding (£000 per year)		No. of sponsors	
No. Staff working on project											
No. PGs working on project											
Duration of project											
Approx. value of funding (£000 per year)											
No. of sponsors											
Please list sponsors:*											
Main Research Outcomes (expected or actual):											

2.2.4 In general, how often are you in contact with funding partners of these projects?	
Formally (e.g. meetings)	
Informally (e.g. phone calls, emails)	

2.3 Teaching Company Schemes (TCS)

2.3.1 How many TCS schemes connected with the oil industry are you involved in?	
--	--

If None, go to section 2.4

2.3.2 Please state the type(s) of company with which you are undertaking these TCS schemes (use the list in the introduction to the questionnaire to assist you)

2.4 Oil Industry Sponsored PhDs

2.4.1 How many oil industry sponsored PhDs do you supervise?	
--	--

If None, go to section 2.5

2.4.2 The following table lists the possible benefits to oil companies sponsoring PhDs. Please circle the number on the scale to indicate what you feel is the **level of importance** to the company of the different benefits of funding PhD research.

TYPE OF BENEFIT	LOW HIGH				
Providing a point of contact to specific academic research	1	2	3	4	5
Providing access to academic research in general	1	2	3	4	5
A cheap way of undertaking research	1	2	3	4	5
Public Relations	1	2	3	4	5
Recruitment	1	2	3	4	5
Other	1	2	3	4	5
Please state:					

2.4.3 How often (per year) are you in contact with the funding partners?	
Formally (e.g. meetings)	
Informally (e.g. phone calls, emails)	

2.5 Sponsored Academic Posts

2.5.1 Is your position in the department oil industry sponsored?	Yes / No
--	----------

If No, go to section 2.6

2.5.2 What is your academic post?	Please Tick
Research Assistant	
Lectureship	
Chair	
Reader	
Other	
Please state:	

2.5.3 Is the post fully funded by industry	Yes / No
Please list sponsor(s):	

2.5.4 What is the duration of the funding?	
---	--

2.5.5 The following table lists the possible motivations to oil companies sponsoring academic posts. Please circle the number on the scale to indicate what you feel is the **level of importance** to the company of the different motivations of funding your academic post.

TYPE OF MOTIVATION	LOW HIGH				
Access to regular consultancy for the company	1	2	3	4	5
Maintaining links with the university	1	2	3	4	5
Access to regular, informal advice for the company	1	2	3	4	5
Public relations	1	2	3	4	5
Recruitment	1	2	3	4	5
Other	1	2	3	4	5
Please state:					

2.5.6 How often (per year) are you in contact with the funding partners?	
Formally (e.g. meetings)	
Informally (e.g. phone calls, emails)	

2.6 Cross – University Research Interactions

2.6.1 Are you involved in any cross university research collaborations?	Yes / No
--	-----------------

If no, go to section 2.7

2.6.2 The following table lists the possible motivations for linking with other universities. Please circle the number on the scale to indicate what you feel is the **level of importance** of the different motivations in undertaking your cross-university research.

TYPE OF MOTIVATION	LOW HIGH				
Extend research capability	1	2	3	4	5
Maintain/improve networks with other academics	1	2	3	4	5
Increase chance of industrial sponsorship	1	2	3	4	5
Increase chance of Research Council funding	1	2	3	4	5
Be able to continue research when staff have moved	1	2	3	4	5
Other	1	2	3	4	5
Please state:					

2.6.3 Do you believe that university-university collaboration increases your chances of attracting industrial sponsorship?	Yes / No
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2.7 Research Conducted Through ITF

2.7.1 Are you aware of the Industry Technology Facilitator (ITF) organisation?	Yes / No
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If No, go to section 3

2.7.2 Have you put forward research proposals to ITF?	Yes / No
If no, please state why not:	

3. YOUR REFLECTIONS ON COLLABORATION

3.1 In general, how would you describe the nature of your working relationships with oil industry sponsors/researchers?	Please Tick
	Excellent
	Good
	Fair
	Poor
	Very Poor
If 'fair' or below, please describe how these could be improved:	

3.2 In your experience, do oil companies sufficiently monitor and direct sponsored research?	Yes / No
If no, please elaborate:	

3.3 The following table lists the possible benefits for the university in gaining industrial sponsorship and collaboration. Please circle the number on the scale to indicate what you feel is the **level of importance** of the different benefits in undertaking your industry-funded research.

TYPE OF BENEFIT	LOW HIGH				
Funding for research	1	2	3	4	5
Funding for staff	1	2	3	4	5
New ideas for research	1	2	3	4	5
Contributions to teaching	1	2	3	4	5
Other	1	2	3	4	5
Please state:					

3.4 Would you say that the quality of the research conducted in collaboration with the oil industry is equivalent to that funded by research councils?	Yes / No
If No, please elaborate:	

3.5 The following table lists the different types of scientific and engineering knowledge transferred from the university in industrial collaboration. Please circle the number on the scale to indicate what you feel is the **level of university contribution** in the different areas when undertaking your industry-funded research.

TYPE OF KNOWLEDGE	LOWHIGH				
The natural world (scientific and engineering theory, properties of materials etc.)	1	2	3	4	5
Design practice (design concepts, creativity in design, competence in design etc.)	1	2	3	4	5
Experimental R&D (experimental procedures, interpretation of results, managing R&D etc.)	1	2	3	4	5
Final product (new product ideas, operating performance, field trials etc.)	1	2	3	4	5
Knowledge of knowledge (locating particular knowledge, specialist facilities or services etc.)	1	2	3	4	5

Thank you for giving up your time to complete this questionnaire.

If you would like to be notified of the outcomes of this research please insert your email address in the space below.

Email address:.....